ADCOMM Engineering Company
Bridging the Gap Between Operations and Technology®

August 18, 2017

Ms. Peggy Glass, Director
Park County 9-1-1
1705 Vaquero Parkway
Bozeman, MT 59718

RE: Livingston Park County 9-1-1 Radio System Current State Report

Dear Ms. Glass:

Please find attached the draft report deliverable for the Livingston Park County 9-1-1 Radio System Engineering project. This report includes all of the deliverables for the project as defined below:

- Current State
- User Needs and Gap Analysis report
- Technology Review
- Recommendations

Please provide ADCOMM with any comments or revisions regarding the draft report.

Sincerely,

ADCOMM Engineering Company

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Joe Blaschka, Jr., P.E.

Draft Report

City of Livingston Park County 9-1-1 Current State, Users Needs, and Gap Analysis Report

Prepared for
Livingston Park County 9-1-1

Prepared by
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Date Prepared
August 18, 2017

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Acronyms and Abbreviations

ADCOMM	ADCOMM Engineering Company
BER	bit error rate
DMR	digital mobile radio
EMS	emergency medical services
ERP	effective radiated power
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FDMA	frequency division multiple access
FirstNet	First Responder Network Authority
FM	frequency modulation
GEOSAT	geostationary earth orbiting satellite
GHz	gigahertz
GPS	global positioning system
IP	Internet Protocol
LEOSAT	low earth orbiting satellite
LMR	land-mobile radio
LPCA	Livingston Peak Community Association
LTE	long-term evolution
MHSB	monitored hot-standby
MHz	megahertz
NIU	network interface unit
NTIA	National Telecommunications and Information Administration
P25	APCO Project 25
PCSO	Park County Sheriff's Office
PD	police department
PSTN	public-switched telephone network
PTT	push-to-talk
RF	radio frequency
SAR	search and rescue
TMDA	time division multiple access
UHF	ultra high frequency
VHF	very high frequency
VoLTE	Voice over LTE
WISP	wireless Internet service provider

Introduction

Executive Summary

The City of Livingston (Livingston) and Park County, Montana, engaged ADCOMM Engineering Company (ADCOMM) to review the existing public safety radio communications systems. This review included the current state of the radio system, technologies used, radio coverage, performance, hardware life-cycle, first responders needs, gap analysis, and recommendations on how to improve deficiencies and meet future needs.

This report details ADCOMM's findings, along with options and recommendations for making improvements to the public safety radio systems in the City of Livingston and Park County.

In September 2015, ADCOMM visited three radio sites in Park County, including the 9-1-1 communications center in Livingston. These sites support the three primary public safety dispatch channels. During the site visits, high-level system information was collected, along with performance measurements to characterize the existing radio systems. ADCOMM found a range of conditions at the sites visited, some of which could accommodate equipment for an upgraded radio system, while others would need some level of improvement. In cases where a fault condition was found or the performance of a particular system was not as expected or within manufacturer specification, personnel from Park County were immediately notified so corrective action could be taken. ADCOMM staff also investigated and visited sites during the summer of 2016 related to fire radio system coverage and operational issues. ADCOMM provided an interim report focused on fire issues at that time.

ADCOMM also developed high-level system drawings and computer-generated coverage predictions of the current radio systems to illustrate the configuration and coverage provided by the existing systems.

Project Purpose and Scope

In March 2015, ADCOMM was contracted by the City of Livingston and Park County to perform a radio system study. In general, the purpose of this project was to determine the current state of the existing public safety two-way radio communication systems in use by stakeholders in the city/county, identify the operational needs of the radio systems' users, identify potential technologies and their applicability to a replacement/upgraded radio system.

Based on this contract, the project consists of the following deliverables:

1. **Phase One: Information Gathering and Education.** The deliverables of Phase One are the Current State Report ***(this report)*** and the User Needs and Gap Analysis. The purpose of this phase is to generate information needed by ADCOMM and by stakeholders to fully understand the existing systems, both for comparison purposes and to identify the needs of the systems' users.
2. **Phase Two: Recommendations Development and Final Study Report.** Using the information gathered during Phase One, Solution Development's deliverable is a list of potential solutions, with rough-order-of-magnitude costs, to the challenges faced by Livingston/Park County's radio systems. The end of Phase Two is a joint meeting to discuss and evaluate each of the potential solutions, with the County decided on one or more potential solutions

for further development. Selection of the solution at this stage begins to set the strategic direction.

3. **Phase Three: Strategic Direction and High-Level Design (Expanded Scope of Work — Not In Initial Report).** During Phase Three, the selected solution is developed further to yield a strategic direction document and a high-level design. The solution will be divided into a series of implementable modules, with estimated costs, implementation time, and impact to the voice systems identified. The High-Level Design will be sufficient to drive the detailed engineering needed as the first step toward acquisition and implementation.
4. **Phase Four: Final Study Report (Expanded Scope of Work — Not In Initial Report).** The Final Study Report is a combination of all the deliverables created in the project with a summary and explanatory text for use in grant justifications and budget discussions. ADCOMM anticipates an in-person delivery of the final report to Livingston/Park County decision makers and stakeholders at a combined meeting.
5. **Phase Five: Solution Selection and Implementation Preparation (Expanded Scope of Work — Not In Initial Report).** Following the Final Study Report release, stakeholders will meet to identify specific solutions for implementation. These solutions will be further developed to produce engineering drawings, detailed system price estimates, and technical specifications for use in procurement and implementation. Solution development will be for voice radio system changes only.

Note that the following are not included in the scope of work for the current project: technical procurement reviews and assistance, vendor selection, technical support during contract negotiations, implementation engineering services, and/or project management.

Current State Report Deliverable

The Current State Report is a section of the Final Report that identifies the performance of the radio systems being used today. ADCOMM approaches this from both a technical and operational perspective; it is important to correlate the user experience with the measured performance of the systems.

1. At each of the County's three radio sites, ADCOMM will:
    a. Identify the relevant equipment by make, model, and serial number (as available) and evaluate each piece of equipment against industry standard lifecycle expectations and manufacturer-identified end-of-life and end-of-support.
    b. Evaluate equipment's actual performance compared to manufacturer's specification, including voice radio and transport mechanisms such as microwave, RF links, leased copper, fiber, and other WAN infrastructure. By measuring basic functionality and consulting maintenance documentation, ADCOMM will gather information related to the technical operation of the system.
    c. Perform cursory visual inspection of associated systems such as grounding, shelter, backup power, battery, alarm reporting, access, tower, feedline, and grounds-keeping/vegetation abatement.
    d. General spectrum analysis at each site to identify potential interfering signals and effective receiver sensitivity measurements at each site.[1]

[1] Identification of any offending transmitters and mitigating the interference is not included in the scope of this project.

2. ADCOMM will interview field users specifically regarding areas with poor reception.
3. ADCOMM will create computer predictions of coverage based on existing County equipment to yield a picture of the systems' performance without interference.
4. ADCOMM will perform field strength measurements at real world locations away from the sites as a "ground truth" verification of users' experience and expected coverage.
5. Combining the predicted coverage, field measurements, and users' experiences, ADCOMM will identify the actual coverage and potential improvements in the systems' performance.

Note that evaluation of field radios/subscriber units is not included in the scope of work for the current project.

Overview

ADCOMM visited the Livingston Park County 9-1-1 communications center[2] and the remote radio sites used for first responder communications during September 2015. During these visits, high-level system information was collected to gain an understanding of current communication capabilities along with an assessment of current site conditions and suitability for a radio system expansion or upgrade.

ADCOMM conducted interviews with dispatcher and first responders to ascertain radio system coverage, operational and technical concerns. Three ride-alongs were schedule on separate days with the Park County Sherriff's Office in both the north and south response areas in the County, including Silver Gate and Cooke City and the Livingston Police Department. Field strength measurements for both Law and Fire Dispatch channels were randomly collected during the ride-alongs. ADCOMM was driven to selected poor coverage areas that the Sherriff's Office desired to see improvements. With the exception of Silver Gate, Cooke City and Wilsall geopolitical boundaries, the other Fire Districts listed many of the same rural radio coverage improvements desired by the Sherriff's Office. ADCOMM also interviewed the Sheriff's Office Search and Rescue to ascertain their common backcountry and wilderness response and staging areas to better understand their communications needs.

Coverage predictions for existing radio sites were developed and can be found in Appendix A. These predictions illustrate where mobile and portable coverage is predicted to be available today. The coverage predictions were compared to collected field strength measurement locations and the poor coverage areas identified during the interviews and ride-alongs. ADCOMM used this data to identify potential radio site locations that would improve first responder radio coverage in urban and rural response areas and along transportation routes.

Livingston 9-1-1 Dispatch Center Radio Resources

Livingston/Park County's consolidated 9-1-1 center dispatches for all law enforcement and most fire and emergency medical services (EMS) agencies in Park County. However, it does not provide primary dispatch service for the towns of Gardiner, Silver Gate, and Cooke City in the southern portion of the county. 9-1-1 and Dispatch radio resources are provided by the National Park Service in these areas.

[2] The 9-1-1 communications department is a City entity with the budget supported equally by the City and the County. The department is governed by a 9-1-1 Advisory Board. The 9-1-1 Communications Advisory Board then makes a recommendation to the City and County for final decisions — http://www.livingstonmontana.org/living/dispatch_911.html.

Telecommunicators (dispatchers) at the 9-1-1 center have access to a variety of radio resources/ channels for communicating with first responders in the field. Dispatch staff use Zetron Integrator RD (48-1) workstation consoles for accessing these radio resources via microwave, wireline telephone circuits, and VHF control stations.

The primary voice dispatch channels used by law enforcement, fire, EMS, and public works agencies employ conventional analog technology using VHF high-band frequencies (150 to 160 MHz). The Livingston Police Department and Park County Sheriff's Office (PCSO) share the same law enforcement dispatch channel. One additional law enforcement channel (Park County Sheriff's Office — PCSO) is available as a backup dispatch channel. The Park County Fire Departments, EMS, and Rural Fire Districts also share their own separate dispatch channel. Both public safety dispatch channels are dispatched by the 9-1-1 center and provide wide area coverage for their respective service areas. Park County Roads operate on their own dispatch channel and are not dispatched by the 9-1-1 center.

In addition, a variety of repeated and tactical simplex channels are operated by Rural Fire Districts and Search and Rescue (SAR), including local P-TACs 1-3, City Fire, state and national mutual aid common channels, such as GOLD, VCALL, and the VTACs. The core mutual aid resources for tactical use are SILVER, RED, WHITE, and PURPLE, as outlined in the State of Montana Mutual Aid and Common Frequencies Manual.[3]

Additional voice channels are available through the Montana Statewide Interoperable Public Safety Radio System, which is a 56-site VHF Project 25 (P25) Phase 1 trunked radio system; however, this system is not normally used for primary communications by Livingston/Park County agencies or the dispatch center. This equipment was originally owned and installed by the State of Montana, but it has since been transferred to the individual counties. The equipment associated with the "state" trunked radio system was not included in ADCOMM's Current State system review.

The following sections describe the configuration of each of the primary radio channels available on the 9-1-1 dispatch consoles. A high-level block diagram of the radio system and dispatch channels is provided in the report.

Livingston PD Dispatch

The Livingston PD and PCSO are both dispatched on the Livingston PD conventional repeated analog channel consisting of a single repeater located at the Meyers Flats radio site approximately 4.5 miles south-southwest of the Livingston 9-1-1 Center. Console audio connectivity for the Law Enforcement dispatch channel is provided via the 4.9 GHz microwave link between the 9-1-1 center and Meyers Flats. Backup access to the channel is available to dispatch via a wireline telephone circuit controlled multichannel base station operating simplex[4] on the repeater output frequency of 155.5950 MHz on a radio site overlooking Livingston called North Hill.

The Law Enforcement channel uses the following frequencies:

- 155.5950 MHz repeater transmit/mobile receive
- 156.2100 MHz repeater receive/mobile transmit

[3] http://sitsd.mt.gov/About-Us/Public-Safety/Spectrum-Mutual-Aid
https://sitsd.mt.gov/Portals/77/docs/Public%20Safety%20Communications/Spectrum%20Program/2015_03_Mutual%20Aid_Manual_Presentation.v2.pdf

[4] Simplex commonly refers to direct, non-repeated communications.

Park County Sheriff's Repeater

The PCSO repeater is a conventional repeated analog channel consisting of a single repeater located at the Meyers Flats radio site approximately 4.5 miles south-southwest of the Livingston 9-1-1 Center. This repeater is used as a backup to the Livingston PD channel. Console audio connectivity for the PCSO repeater channel is provided via the 4.9 GHz microwave link between the 9-1-1 center and Meyers Flats. Backup access to the channel is available to dispatch via a wireline telephone circuit controlled multichannel base station operating on the repeater output simplex frequency 154.8600 MHz at North Hill.

The Law Enforcement channel uses the following frequencies:

- 154.8600 MHz repeater transmit/mobile receive
- 155.3700 MHz repeater receive/mobile transmit

Park County Fire/EMS Dispatch Channel

The Livingston FD and Park County Fire Districts dispatch channel is a conventional repeated analog channel consisting of a single repeater located at the Meyers Flats radio site approximately 4.5 miles south-southwest of the Livingston 9-1-1 Center. Console audio connectivity for the Fire/EMS dispatch channel is provided via the 4.9 GHz microwave link between the 9-1-1 center and Meyers Flats. Backup access to the channel is available to dispatch via a wireline telephone circuit controlled multichannel base station operating simplex on the repeater output frequency 154.415 MHz at North Hill. A second repeater shares this Fire/EMS channel and is also a conventional repeated analog channel consisting of a single repeater located at the Wilsall Mountain radio site directly west of Wilsall on Old Flathead Road. Dispatch access to the Wilsall Mountain (North Repeater) is via a wireline telephone circuit controlled multichannel base station[5] operating on 154.415 / 158.8350 MHz at North Hill.

The Fire/EMS channel uses the following frequencies:

- 154.4150 MHz repeater transmit/mobile receive
- 158.8350 MHz repeater receive/mobile transmit

Park County Road and Bridge Dispatch Channel

The Park County Roads Department dispatch channel is a conventional repeated analog channel consisting of a single repeater located at the Meyers Flats radio site approximately 4.5 miles south-southwest of the Livingston 9-1-1 Center. Console audio connectivity for the Park County Road and Bridge channel is provided via the 4.9 GHz microwave link between the 9-1-1 center and Meyers Flats. There is no backup system for this channel.

The Park County Road and Bridge channel uses the following frequencies:

- 151.0775 MHz repeater transmit/mobile receive
- 156.1050 MHz repeater receive/mobile transmit

Other VHF repeater and simplex channels are operated by PCSO for Search and Rescue and various fire districts in Park County. Unless listed above, these channels are unavailable to the 9-1-1 Center.

[5] The 10-channel base station at North Hill can only operate on one channel at a time. In the event the Meyers Flats radio site goes down, the dispatch center will have to make a choice on which of the 10 VHF channels they will operate on.

Livingston/Park County Radio Sites

Introduction

The Livingston Park County 9-1-1 Center operates a multi-channel, multi-site VHF analog voice radio system that provides voice communications for Law, Fire, and EMS.

Each site is configured differently, based on number of channels, type of standalone conventional base stations or repeaters and types of installed equipment (differing manufacturers). Connectivity between the sites is made possible by combinations of microwave, phone lines, or control stations.

ADCOMM was contracted to inventory and to perform an evaluation of the current state of the VHF voice radio system. ADCOMM performed the site visits in September of 2015. From this exercise, ADCOMM was to provide a general assessment of the sites.

The locations of the sites that ADCOMM visited are shown in Figure 1. The names of these sites are listed in Table 1. Please see Table B-1 in Appendix B for the listings of voice channels per site. Figure 2 displays the 9-1-1 remote radio sites control connections.

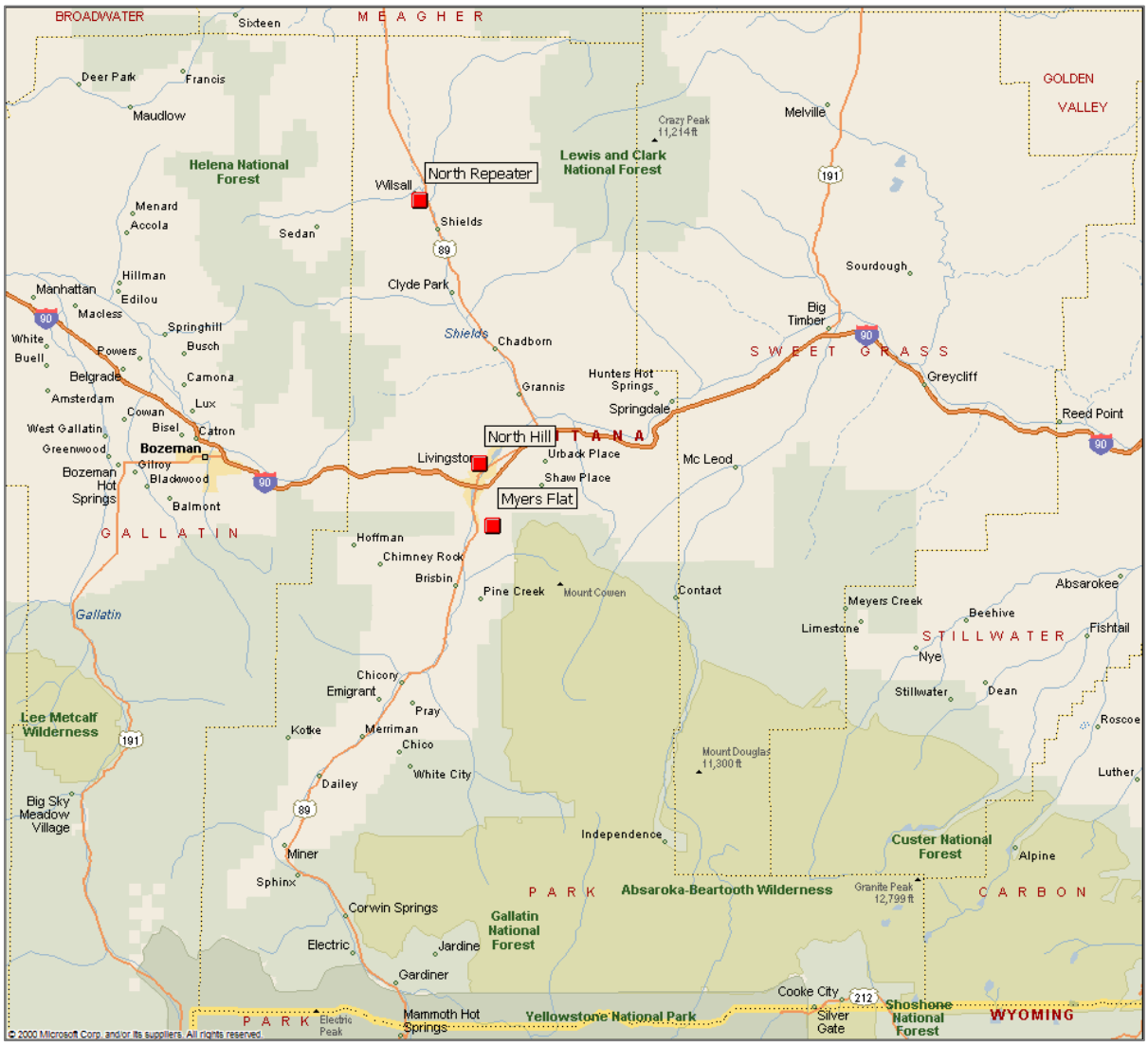


FIGURE 1
Locations of All Livingston/Park County 9-1-1 Radio Communications Sites

TABLE 1
Site Names

Site Name	Voice Channel	Voice Channel Site Connectivity
North Hill	Yes	Telephone
Wilsall Mountain	Yes	None
Meyers Flats	Yes	Microwave

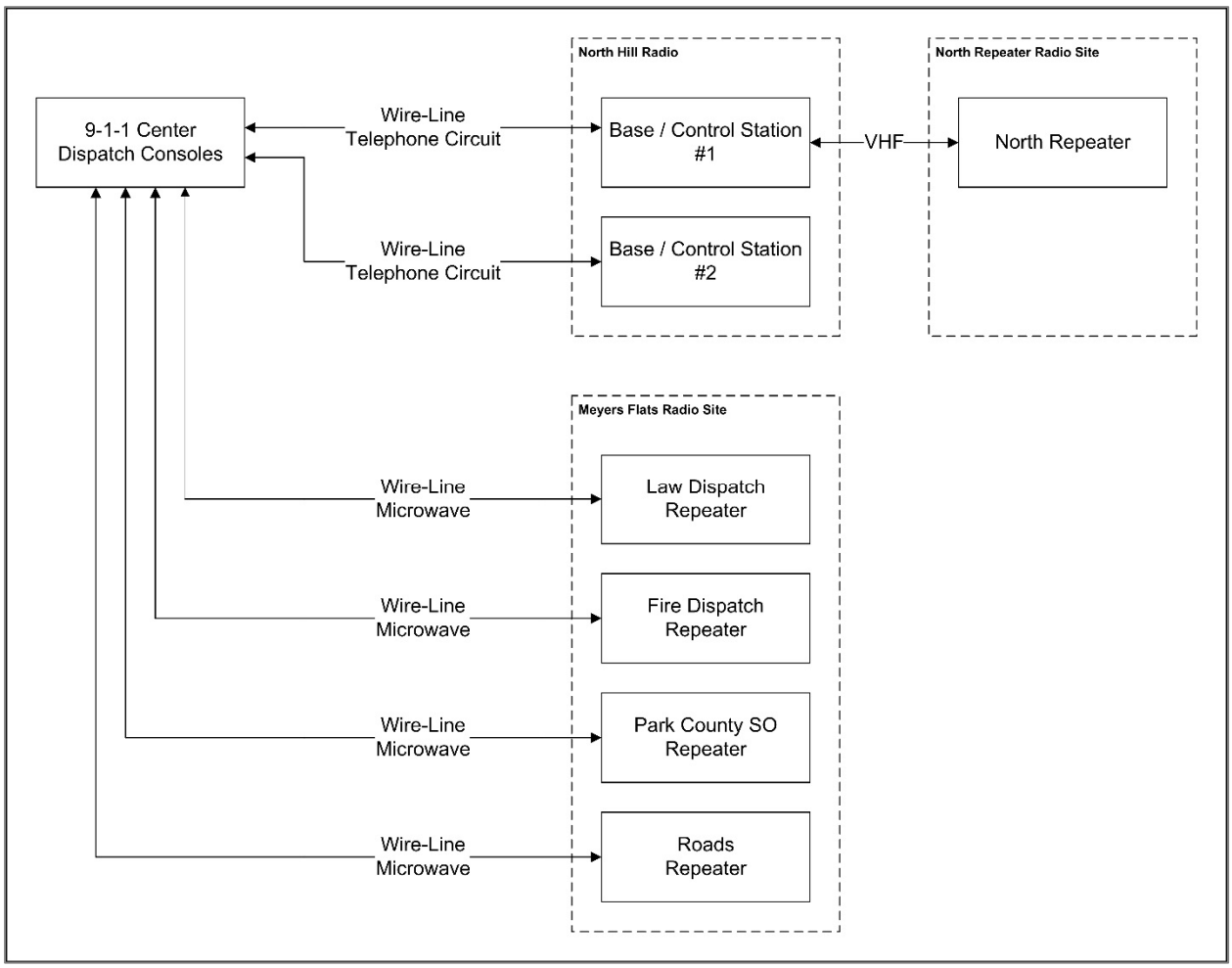


FIGURE 2
9-1-1 Remote Radio Sites Control Connections

Radio System Summary

The Livingston Park County 9-1-1 Center operates several voice channels that covers different areas of the county through the combination of conventional repeaters, base stations,[6] and control stations.[7] The channels and access is listed in Table 2.

[6] A base station is commonly referred to as a stationary two-way radio that is used to communicate with mobile radios on one or more channels. FCC licensing requires the identification (FB station class) of this type of radio under Part 90 license rules and regulation.

Please see Table B-1 in Appendix B for the listings of 9-1-1 Dispatch voice channel frequencies and tones per site. Tactical repeaters for Paradise Valley, SAR, and Park Service dispatch repeaters are not used by the Livingston Park County 9-1-1 Dispatch and thus are not listed in this report.

TABLE 2
Sites Visited by ADCOMM and Listing of Livingston Park County 9-1-1's Radio Equipment

Channel Name	Site Name	Wire-Line Controlled Conventional Repeaters	Standalone Conventional Repeaters	Base / Control Station	Dispatch Access
Law Dispatch	Meyers Flats	X			Microwave Channel Bank
Fire Dispatch	Meyers Flats	X			Microwave Channel Bank
Park County SO	Meyers Flats	X			Microwave Channel Bank
Park County Roads	Meyers Flats	X			Microwave Channel Bank
Fire Dispatch (North)	North		X		Control Station
Law Direct	North Hill			X	Radio #1 Base Station Mode
Fire Dispatch (North)	North Hill			X	Radio #1 Control Station Mode
South	North Hill			X	Radio #1 Control Station Mode
Park County SO Direct	North Hill			X	Radio #2 Base Station Mode
Fire Direct (Meyers Flats)	North Hill			X	Radio #2 Base Station Mode
Fire Direct (North)	North Hill			X	Radio #2 Base Station Mode
Fire Dispatch (North Reverse)	North Hill			X	Radio #2 Base Station Mode
City Fire	North Hill			X	Radio #2 Base Station Mode
Gold	North Hill			X	Radio #2 Base Station Mode
Ruby / Garnet	North Hill			X	Radio #2 Control Station Mode
PTAC 1	North Hill			X	Radio #2 Base Station Mode
PTAC 2	North Hill			X	Radio #2 Base Station Mode
TAC 3	North Hill			X	Radio #2 Base Station Mode

[7] A control station is commonly referred to as a stationary two-way radio that is used to communicate with mobile radios on one or more channels using a repeater. FCC licensing requires the identification (FX station class) of this type of radio under Part 90 license rules and regulation.

Standalone conventional repeaters are automatic relay stations usually located in high locations, such as mountain tops or tall buildings, near the primary users' operational service area. When installed in an advantageous location, repeaters allow two or more stations to communicate over large areas, beyond that of direct (direct, simplex, or talk around) communications.

Standalone conventional repeaters are able to receive on one radio frequency and simultaneously transmit on another radio frequency; the two frequencies are often referred to as the repeater pair.

Dispatch communicates through the standalone conventional repeaters through a direct wire-line connection and through a control station. Direct wire-line connections provide talk-through capability. In the event the wire-line connection is lost, the repeater will continue to operate. Control station access is the equivalent accessing the repeater through a fixed mobile connected to the dispatcher's console.

In the Livingston Park County 9-1-1 radio system, a combination of Motorola GTR 8000s and Kenwood TKR-750 repeaters and Harris Mastr III base/control stations are used for dispatch.

One microwave link, two telephone circuits, and a control station is used for the transport of repeater/base/control station audio to and from dispatch, Meyers Flats, and North Hill.

In a typical installation, four-wire connections to a microwave system are provided by channel banks. A channel bank provides multiple four-wire E&M connections; a single connection is allocated to a single radio. The multiple four-wire E&M connections allow for multiple radios and other devices to share the single microwave link. Livingston Park County 9-1-1 uses a pair of 4.9 GHz Motorola Cambium PTP 600 Series Point-to-Point Wireless Ethernet Bridge microwave radios and RAD Data Communications IPmux-1E "TDM Pseudowire Access Gateways" to provide traditional analog four-wire E&M connections to/from Meyers Flats.

General Assessment

During the site evaluation process, ADCOMM assessed the following:

- Inventory of Livingston Park County 9-1-1's equipment
- Radio system performance
  - Voice channel transmit power measurement
  - Voice channel receiver sensitivity measurement
- General installation practices
  - Rack and equipment installations
  - Grounding
  - Cable management
- General site assessment
  - Access requirements
  - Backup power availability
  - Shelter environmental control
  - Vegetation upkeep
  - Available space for future growth

General Installation Practices

As part of the general physical installation assessment, the following was noted:

- Signs of excessive wear and tear, such as gouges, dents, or other noticeable physical damage
- Signs of natural forms of aging, such as rust, mold, peeling paint, or peeling labels
- General installation quality of the equipment
- Plumb and true installations of racks and equipment

Cable management is the manner in which cables are routed and dressed between two connecting devices. While there are no standards for cable management, the following was noted in trying to access the cable management practices:

- Free hanging and loose cables that could easily be snagged
- Coiled cables not dressed and or physically secured
- Poor terminations based on visual inspections

Poor grounding is an issue that could reduce the life of the components of a radio system. In the event of a lightning strike or a power surge, the electrical energy from these events looks for the path of least resistance to ground. In the event that any of Livingston Park County 9-1-1's equipment becomes a part of this path, good grounding will provide a path outside of the equipment itself. Good grounding requires a shelter ground system and a proper connection to the ground system. As a part of the assessment, the following was noted:

- Existence of a master ground bus inside the shelter
- Existence of a ground halo inside the shelter
- Connections between equipment, racks, and the site's ground system
- Installation practices of PolyPhaser lightning suppression devices
- Feed line ground kits

9-1-1 Dispatch Center

Date Visited: Tuesday, September 1, 2015
Latitude: 45° 39' 47.3" N
Longitude: 110° 33' 20.8" W
Elevation (approx.): 4,490 feet AMSL

The Livingston Park County 9-1-1 Center is located inside the City-County Complex in downtown Livingston at 414 East Callender Street, Livingston, Montana 59047 (see Figures 3, 4, and 5), and is accessible by paved roads.

The 9-1-1 radio console, telephones, and computer aided dispatch equipment is located in a separate equipment room away from the dispatch floor. There is no dedicated antenna support structure. The building has a backup generator.

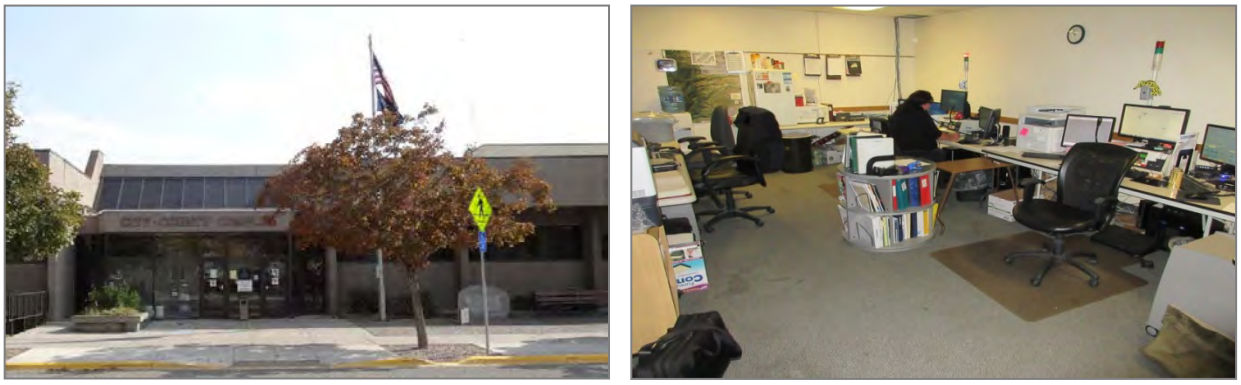


FIGURE 3
Livingston Park County 9-1-1 Dispatch Center

The site assessment in the following sections only addresses the radio system within the equipment room, not the dispatch center floor, telephone, or logging equipment.

Equipment List — Radio

There is no dispatch VHF control station or base station radio equipment at this facility.

Tower and Antenna Systems

There is no antenna support structure at this facility.

Equipment List — Microwave and Intersite Connections

The Livingston Park County 9-1-1 microwave and four-wire wire-line circuits mux equipment for the 9-1-1 Center is listed in Table 3.

The mux may have two additional four-wire wire-line circuits available for future use; the available capacity will need to be verified.

FIGURE 4
Livingston Park County 9-1-1 Center Equipment Room

TABLE 3
Microwave and Channel Bank Equipment Inventory

Equipment	Function	Target Location/Purpose
Motorola PTP 600	Microwave	Meyers Flats
RAD Data IPmux-1E	Mux	Local 4W E&M Connections

FIGURE 5
9-1-1 Center to Meyers Flats Microwave Radio and Panel Antenna

Site and Equipment Grounding

There is inconsistent rack grounding. No vertical rack ground buses installed.

Not all of the individual pieces of Livingston Park County 9-1-1's equipment are connected to the rack ground bus.

Backup Power

Backup power is provided by a Generac generator. No dedicated UPS was located.

General Site Condition

The equipment is installed in the equipment room that is undersized.

There is little space for additional equipment or racks.

Not all racks with equipment are seismically braced or restrained by the cable trays.

The installation, cable management practices, and cleanliness is lacking.

Temperature control is provided by an unidentified HVAC system.

Recommendations

1. There are no collocated VHF control or base stations to communicate directly with the Meyers Flats repeaters. In the event of a microwave and telephone line outage, Livingston Park County 9-1-1's Dispatch Center would be off the air beyond the use of handheld radios.
2. Add adequate grounding of Livingston Park County Dispatch Center's equipment.
3. Add adequate cable management of Livingston Park County Dispatch Center's equipment.
4. Develop detailed line drawings and interconnections of Livingston Park County Dispatch Center's equipment

Meyers Flats

Date Visited: Monday, September 5, 2015
Latitude: 45° 35' 51.1" N
Longitude: 110° 32' 48.9" W
Elevation (approx.): 6,519 feet AMSL

The Meyers Flats radio site is located 4.5 miles south-southeast of the 9-1-1 Dispatch Center on private property (see Figure 6). Secure access to the radio site requires traveling approximately 2.3 miles beyond a Livingston Peak Community Association (LPCA) locked gate.

The shelter was built by Fibrebond and is approximately 12 feet by 24 feet. A propane generator is housed in the separate room of the shelter. The antenna support structure is a 100-foot-tall three-leg self-supporting Sabre S3R-SD tower.[8]

FIGURE 6
Meyers Flats Tower and Shelter

This shelter is occupied by Livingston Park County 9-1-1, Livingston Memorial Hospital, and an unidentified and inactive Daniels 154.415 MHz[9] base station and a Harris Mastr III VHF repeater.

[8] Sabre ID tag lists tower as 150 feet.'

[9] The Daniels 154.415 MHz TX & RX base station is the same output frequency as the collocated Fire Dispatch base station operating on TX 154.415 MHz, is not connected to the microwave, and appears to be turned off.

Equipment List — Radio

The Livingston Park County 9-1-1 radio equipment for this site is listed in Table 4 and shown in Figure 7.

TABLE 4
Radio Equipment Inventory and Measurements

Channel	Equipment	Usage	Power	Measured Transmit Output	Measured Combiner Transmit Output	Measured Receiver Sensitivity	Measured Site Noise	Measured Receiver Desense
Law Dispatch	Motorola GTR 8000 Model #T7039A Serial #112CQ1149	Repeater	120 VAC	75 Watts	50 Watts	-122 dBm	6 dB	10 dB
Fire Dispatch	Motorola GTR 8000 Model #T7039A Serial #112CQT1141	Repeater	120 VAC	75 Watts	48 Watts	-120 dBm	5 dB	0 dB
Park County SO	Motorola GTR 8000 Model #T7039A Serial #112CQT1144	Repeater	120 VAC	75 Watts	48 Watts	-121 dBm	10 dB	14 dB
Park County Roads	Motorola GTR 8000 Model #T7039A Serial #112CQT1143	Repeater	120 VAC	75 Watts	51 Watts	-121 dBm	5 dB	0 dB

FIGURE 7
Meyers Flats Radio Equipment

Tower and Antenna Systems

The antenna support structure is a 100-foot-tall three-leg self-supporting Sabre S3R-SD tower and is adjacent to the shelter.

The Livingston Park County 9-1-1 antenna systems for this site are listed in Table 5.

TABLE 5
Antenna Systems Inventory

Usage	Feed Line Type	Antenna Type	Antenna Height	Antenna Azimuth	Tower Leg
VHF Receiver Multicoupler Antenna	1/2-inch	2-Bay Dipole Offset Pattern	98'	~265°	West
VHF Transmitter Combiner Antenna	1/2-inch	2-Bay Dipole Offset Pattern	65'	~265°	West
4.9 GHz Microwave	CAT5	Panel	98'	~354°	West

The transmitter combiner and receiver multicoupler cables between the equipment rack and PolyPhasers at the cable entry are using sub-standard Type-N male connectors. The Type-N male connector at the transmitter combiner came apart during testing when hand tightening the connector. The connector was repaired; however, it should be replaced.

There is 10 dB of receive desense[10] on the Law Dispatch repeater (labeled LIV PD) when keyed and 14 dB of receive desense on the Park County SO repeater when keyed. The existing new 155.280 to 158.835 MHz bandpass only receiver multicoupler appears to have replaced the old Comprod receiver multicoupler pass and notch system that is no longer in service and is still at the site. The 155.595 MHz Law Dispatch transmitter should not be within the receiver multicoupler 155.280 to 158.835 MHz bandpass. Additional filtering is required for the Park County SO repeater receiver.

The transmit and receive antennas are closely spaced vertically to each other. At a minimum, the vertical separation should be at least 50 feet from the base of the top receive antenna to the tip of the bottom transmit antenna in order to achieve 60 dB of isolation (Appendix C, Photograph MF-1).

The transmit antenna transmission line to antenna jumper is short and pulled tight against the base of the antenna. This jumper should be replaced with a proper length jumper using proper hangers versus plastic cable ties (Appendix C, Photograph MF-2).

Equipment List — Microwave and Intersite Connections

The Livingston Park County 9-1-1 microwave and four-wire wire-line circuits mux equipment for the 9-1-1 Center is listed in Table 6 and shown in Figure 8.

The mux may have two additional four-wire wire-line circuits available for future use; the available capacity will need to be verified.

[10] Receive desense is where strong other signals operating on frequencies near the affected receiver cause the receiver to lose sensitivity. In this case, 10 dB of desense means the receiver is 1/10 the sensitivity when desense occurs. Another way of looking at it is a 5-watt portable would need to transmit at 50 watts to override the desense.

TABLE 6
Microwave and Channel Bank Equipment Inventory

Equipment	Function	Target Location/Purpose
Motorola PTP 600	Microwave	9-1-1 Dispatch Center
RAD Data IPmux-1E	Mux	Local 4W E&M Connections

FIGURE 8
Meyers Flats to 9-1-1 Center Microwave Radio and Panel Antenna

Site and Equipment Grounding

The site has a master ground bus and a ground halo.

The equipment rack is properly grounded.

Backup Power

Backup power is provided by a propane generator located in a separate room inside the shelter (Appendix C, Photograph MF-3).

General Site Condition

The installation practices inside the shelter are clean. Cable management is contained with cable trays on the ceiling and cable stand-offs on the racks (Appendix C, Photograph MF-4).

Temperature control is provided by two Bard wall-mount HVAC units (Appendix C, Photograph MF-5).

No safety equipment (first aid kit or eyewash station).

Vegetation growth should be cleared at least once a year (Appendix C, Photograph MF-6).

Recommendations

1. Replace the existing transmitter combiner and receiver multicoupler to cable entry cables with 1/2" Superflex Foam Coaxial Cable (FSJ4-50B) and the appropriate Type-N Male

connectors (F4PNMV2-HC) that have threaded clamping nuts that will not come apart when properly tightened.

2. Resolve the receiver desense on Law Dispatch and Park County SO repeaters.
3. Replace transmit antenna transmission line jumper and use proper cable hangers.
4. Remove and repurpose the unused VHF multicoupler/combiner equipment[11] (Appendix C, Photograph MF-9).
5. Remove and repurpose the unused Harris Mastr III base station (Appendix C, Photograph MF-11).
6. Schedule yearly vegetation growth removal.

[11] ADCOMM recommends the repurposing of this equipment for system improvements at North Hill.

Wilsall Mountain – North Repeater Radio Site

Date Visited: Monday, September 3, 2015
Latitude: 45° 59' 34.7" N
Longitude: 110° 40' 25.2" W
Elevation (approx.): 5,292 feet AMSL

The North radio site is located 0.6 mile west of Wilsall on private property. Open access to the radio site is a short paved and gravel road off of West Clark Street to Old Flathead Road.

The wooden shelter with metal siding appears to be custom built and is approximately 6 feet by 6 feet. The antenna support structure is a 40-foot pole (see Figure 9).

FIGURE 9
Wilsall Mountain Repeater Shelter

This shelter is occupied by the Wilsall Rural Fire District No. 3 owned and operated Kenwood VHF repeater and unidentified private or commercial wireless Internet service providers (WISP)[12] equipment.

Equipment List — Radio

The Wilsall Rural Fire District No. 3 radio equipment for this site is listed in Table 7 and shown in Figure 10.

[12] https://en.wikipedia.org/wiki/Wireless_Internet_service_provider

TABLE 7
Radio Equipment Inventory and Measurements

Channel	Equipment	Usage	Power	Measured Transmit Output	Measured Combiner Transmit Output	Measured Receiver Sensitivity	Measured Site Noise	Measured Receiver Desense
Fire Dispatch	Kenwood Model #TKR-750 Serial #B0500294	Repeater	120 VAC	40 Watts	30 Watts	-121 dBm	5 dB	0 dB

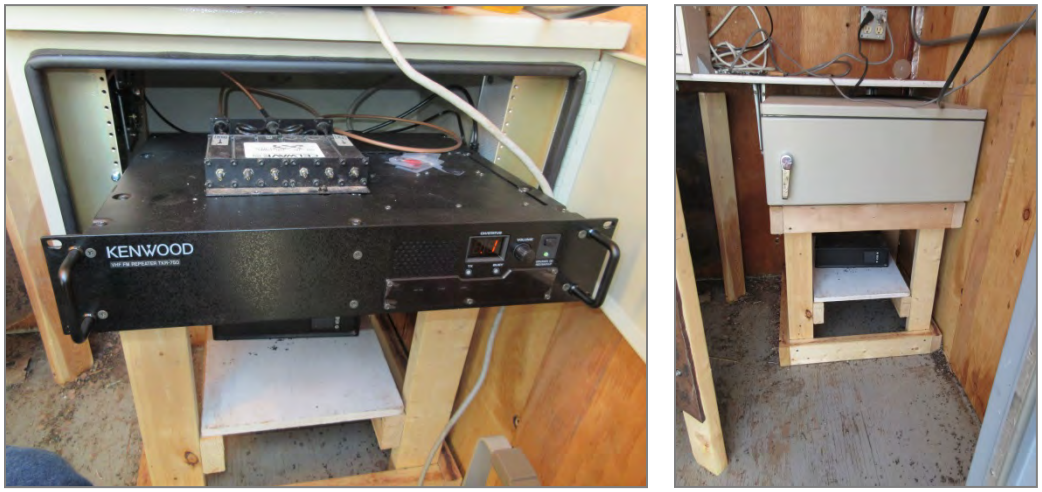


FIGURE 10
North Repeater Radio Equipment

Tower and Antenna Systems

The antenna support structure is a 40-foot wooden pole adjacent to the shelter.

The Wilsall Rural Fire District No. 3 antenna system for this site is listed in Table 8.

TABLE 8
Antenna Systems Inventory

Usage	Feed Line Type	Antenna Type	Antenna Height	Antenna Azimuth	Tower Leg
VHF Repeater	LMR-400	Omni Directional	60’	360º	N/A

A Celwave mobile duplexer model TDD-7300 is used in order to operate the repeater on a single VHF antenna at the site.

Equipment List — Microwave and Intersite Connections

There are no microwave or telephone circuit connections at this site.

Site and Equipment Grounding

There is no external or internal ground bus or ground halo (Appendix C, Photograph N-1A).

The equipment cabinet is not properly grounded.

Backup Power

No backup power is at this site. A non-operational Tripp-Lite UPS is installed below the repeater cabinet. The APC UPS is only powering the WISP equipment.

General Site Condition

The repeater is in an unclean environment. There is considerable rodent droppings and nesting materials on the equipment shelf and the floor.

The shelter is riddled with bullet holes. The repeater is being protected with a two-sided steel plate armament (Appendix C, Photographs N-1A, N-1B, and N-2).

No temperature control is provided.

No safety equipment (fire extinguisher or first aid kit).

Vegetation growth should be cleared at least once a year (Appendix C, Photograph N-3).

Recommendations

1. Install proper site grounding at the site, including a master ground bar on the inside of the shelter.
2. A PolyPhaser is installed on the outside of the shelter. These devices are not designed for this environment. The PolyPhaser should be replaced and put inside the shelter (Appendix C, Photograph N-4).
3. Install a generator for backup power.
4. Install AC power line lighting protection.
5. Improve the security of the site with a proper door lock and latch protector.
6. Schedule yearly vegetation growth removal.
7. The Wilsall Fire Department FCC call sign WQJC300 Location 3 repeater frequency for this site is incorrect. The license should be modified to reflect the correct repeater frequency 154.415 MHz (FB2) and the mobile frequency 158.835 MHz (MO).

North Hill

Date Visited: Tuesday, September 1, 2015
Latitude: 45° 40' 25.9" N
Longitude: 110° 34' 02.9" W
Elevation (approx.): 4,891 feet AMSL

The North Hill radio site is located 0.9 mile northwest of the 9-1-1 Dispatch Center on private property. Secure access to the radio site requires traveling approximately 0.2 mile beyond a locked chain across the gravel road.

The cinderblock shelter is approximately 10 feet by 10 feet. The antenna support structures include a 95-foot Rohn 45 guyed tower, 30-foot Rohn 25 tower, and a 40-foot pole (see Figure 11).

FIGURE 11
North Hill Towers, Pole, and Shelter

This shelter is occupied by Livingston Park County 9-1-1, NOAA Weather Radio All Hazards WNG682 162.525 MHz transmitter, and three unidentified radios that are turned off.

Equipment List — Radio

The Livingston Park County 9-1-1 radio equipment for this site is listed in Table 9 and shown in Figure 12.

TABLE 9
Radio Equipment Inventory and Measurements

Channel	Equipment	Usage	Power	Measured Transmit Output	Measured Receiver Sensitivity	Measured Site Noise	Measured Receiver Desense
Law Base Station	Harris Mastr III	Base Station & Control Station	120 VAC	90 Watts	-114 dBm	5 dB	16 dB
Fire Base Station	Harris Mastr III	Base Station & Control Station	120 VAC	100 Watts	-119 dBm	5 dB	16 dB

FIGURE 12
North Hill Radio Equipment

Tower and Antenna Systems

Three antenna support structures are used at the site: a 95-foot Rohn 45 guyed tower, 30-foot Rohn 25 tower, and a 40-foot pole. Only two structures are used for the Livingston Park County 9-1-1 antenna systems. The Law radio is using the 95-foot guyed tower and the Fire radio is using the 30-foot tower that is bracketed to the shelter.

The Livingston Park County 9-1-1 antenna systems for this site are listed in Table 10.

TABLE 10
Antenna Systems Inventory

Usage	Feed Line Type	Antenna Type	Antenna Height	Antenna Azimuth	Tower Leg
Law Radio Antenna	RG-8	Omni Directional[13]	40’	360º	Southeast
Fire Radio Antenna	LMR-400	Omni Directional	30’	360º	Top Mounted

[13] The Law base station/control station is utilizing a unity gain (0 dbi) omni directional antenna.

There is 16 dB of receive desense on one or more of the base station/control station channels. Livingston Park County 9-1-1 should consider auditing and removing all unused antennas and transmission lines in order to ascertain if using the 95-foot tower will allow for Livingston Park County 9-1-1 the option of moving their antennas "vertically away" from the NOAA continuously keyed transmitter. Using a shared tower top receive antenna and repurposing the Meyers Flats unused receiver multicoupler with additional filtering may help improve the receiver performance.

Equipment List — Microwave and Intersite Connections

There are no microwave connections at this site. Two two-wire telephone circuits are in service to provide the Law and Fire base station/control station voice and tone-controlled connections to the dispatch center (see Table 11).

TABLE 11
Telephone Circuit Inventory

Equipment	Function	Circuit ID	Target Location/Purpose
Telephone Company NIU[14]	Voice Grade 2-Wire Circuits	6-410447-5PR	9-1-1 Dispatch Center Law Radio
Telephone Company NIU	Voice Grade 2-Wire Circuits	Unavailable	9-1-1 Dispatch Center Fire Radio

Site and Equipment Grounding

The site has a master ground bus for some of the transmission lines and telephone circuits. A low-level ground halo system has been installed.

Some of the equipment is properly grounded.

Backup Power

Backup power is provided by batteries located inside the shelter; however, the battery condition is questionable (Appendix C, Photograph NH-1).

General Site Condition

The base stations/control stations are in an unclean environment. Rodent droppings and installation debris litter the floor.

No single point cable entry location for proper grounding and cable management.

No generator is provided.

No temperature control is provided

Unused cabinet and equipment, transmission lines, and antennas should be removed.

Recommendations

1. Install proper tower and shelter grounding at the site, including an expanded master ground bar on the inside of the shelter.
2. Install AC power line lighting protection.

[14] Network interface unit is a device that serves as the demarcation point between the telephone company and the customer's wiring.

3. Install a generator for backup power.
4. Install air conditioning.
5. Install safety equipment.
6. Install bollards to protect guyed tower anchors.
7. Install backup batteries for the Law base station/control station.
8. Repair inoperative interior lighting
9. Reprogram and test both the Fire and Law base stations/control stations for proper narrowband[15] operation per FCC rules and regulations.
10. Reprogram and align both the Fire and Law base stations/control stations for proper telephone line circuit levels (TX and RX 1.5 kHz FM deviation = - 10dB at 1 kHz test tone wireline levels)
11. Livingston Park County 9-1-1 should consider auditing and removing all unused antennas and transmission lines in order to ascertain if using the 95-foot tower will allow for Livingston Park County 9-1-1 the option of moving their antennas "vertically away" from the NOAA continuously keyed transmitter. Using a shared tower top receive antenna and repurposing the Meyers Flats unused receiver multicoupler with additional filtering will help improve the receiver performance.
12. Remove unused cabinets and equipment.

Summary

The existing radio sites used to support Livingston/Park County's public safety voice dispatch systems visited and evaluated by ADCOMM reveal a wide variety of conditions. In some cases, sites are generally in adequate condition, while in others site improvements will be required to adequately support an upgraded radio system. In cases where existing equipment or antenna systems were found to be faulty, Livingston/Park County was immediately notified so corrective actions could be taken.

[15] https://www.fcc.gov/general/narrowbanding-overview.
http://transition.fcc.gov/pshs/docs/clearinghouse/guidelines/Narrowbanding_Booklet.pdf

Findings

User Interviews

ADCOMM conducted individual on-site and telephone interviews with dispatchers and first responders throughout Park County. The objective was to collect high-level information about the existing 9-1-1 radio communications systems, identify known coverage problems, and determine desired improvements to the radio system.

The following is a summary of findings and issues that were identified from the feedback.

Radio Coverage, Operational and Technical Concerns Summary

Users' overall perceptions of the radio system varied greatly. A couple of departments identified spot radio coverage problems, while many others stated they have significant communications problems throughout their response area.

A common radio coverage theme heard during the dispatch, law, and fire first responder interviews were:

We need countywide coverage in the areas we serve – we've never had it.

We need I90 343-354 coverage to the county line.

We need coverage within the [Livingston] *City-County Building.*

We hear pager tones only and no voice on a regular basis.

Handpack [portable radio] *coverage inside buildings and around town* [Livingston] *is a major problem.*

Radio coverage has gotten worse since we narrowbanded – less coverage.

Interviewees identified radio coverage problem areas:

Livingston – City-County Building
Livingston – Hospital
Livingston – Brick Buildings
Livingston – Urgent Care Center
Livingston – Inside McDonalds
Livingston – Stoplights
Livingston – Town Pump East and West
Livingston – Albertsons
Livingston – Many buildings in downtown
North County – Brackett Creek Road
North County – Clyde Park
North County – Castle Mountain Road near Willow Creek

North County – Looking Glass Creek

North County – Upper Cottonwood Creek

North County – Flathead Creek Road

North County – Rice Creek

South County – Swingley Road

South County – Beaver Creek

South County – Mill Creek Road and many areas off pavement

South County – East Mill Creek Road

South County – West Fork Mill Creek Road

South County – Trail Creek Road

South County – Tom Miner Creek Road

South County – Big Creek Road

South County – West Boulder Road

South County – Main Boulder Road (in and out via Sweet Grass County)

South County – Mission Creek Road

South County – Everywhere[16] *south past milepost 16 on U.S. Highway 89 to Gardiner*

A common Operation and Technical concerns theme heard during the dispatch, law, and fire first responder interviews were:

The North repeater shouldn't be shared [on the same fire channel] *with Meyers Flats.*

The North repeater should be on a different channel.

Sometimes dispatch mutes the North Repeater channel on the dispatch console when there's a lot of traffic and then they miss our calls.

Clyde Park and Wilsall should be toned out first on the North repeater and then on Meyers Flats.

Calling in for call times takes a lot of time away from the radio.

We need CAD in our vehicles to help dispatch.

Eliminate third party calls to dispatch.

Dispatch needs a minimum of two dispatchers on duty.

We need an encrypted tactical channel for law enforcement.

ADCOMM observed radio interference during the ride-along:

Some stoplight locations in Livingston

Town Pump gas stations

PCSP patrol vehicle electrical noise (likely electrical fuel pumps)

Point-of-sale computer systems around Livingston

[16] The PCSO responds to calls in and around Gardiner, Silver Gate, and Cooke City. Deputies use the National Parks Service radio system and cell phones (where available) when traveling to and from these areas and for general law enforcement communications. The Sheriff would like his deputies to be able to communicate directly with the Livingston 9-1-1 Center and other Park County deputies when responding to calls or on patrol in Gardiner, Silver Gate, and Cooke City.

Radio Propagation Coverage Predictions

Background Information on Radio Propagation Coverage Predictions

ADCOMM developed radio coverage propagation predictions for each existing and recommended radio site. The Longley-Rice[17] propagation model was used to make the computer computations. Our software takes into account the transmitter power levels, losses, antenna gain and pattern, site noise, terrain elevation data, land use attenuation, and mobile receive height of 2 meters to produce the predicted field strengths in the desired service areas. The recommended sites radio coverage predictions reflect the maximum allowed FCC Safe Harbor ERP[18] limits within the 40 km (24.8 mile) service area radius covered in FCC rules and regulations under Part §90.205.[19]

The propagation radio coverage predictions did not take into account any ambient interference from commercial carriers and man-made obstacles in the desired service areas, as this was beyond the scope of this report. However, all existing and proposed radio site noise levels should be measured and this data used to refine the expected talk-in coverage during the detailed design phase of the proposed project.

The provided "street level" coverage predictions are computer predictions using terrain data provided by the U.S. Government and have limitations related to the resolution of the data and how the software performs the computations. The predictions use terrain data that is spaced at approximately 100-meter intervals. This means there may be localized areas where coverage is lower than predicted because of dips in the terrain that are less than 100 meters in size. Computer-generated coverage predictions are based on models that have been extensively studied. However, they are still only computer models and have limitations related to the terrain, natural vegetation effects, and calculation process. They do, however, provide a good general indication of coverage from an individual site and multiple simulcast sites.

Radio Propagation Coverage Prediction Definitions

For VHF public safety-grade narrowband analog talk-out coverage, the coverage map colors approximately represent the following:

1. Gray: mobile only, but less the 50 percent reliability
2. Blue: mobile only, 34 to 51 dBu
3. Green: portable on-street, 51 to 61 dBu
4. Yellow: portable light building, 61 to 69 dBu
5. Red: portable medium commercial buildings, greater than 69 dBu[20]

For VHF public safety-grade narrowband analog talk-in coverage, the coverage map colors approximately represent the following:

[17] Longley-Rice propagation model: https://en.wikipedia.org/wiki/Longley%E2%80%93Rice_model.

[18] Effective radiated power (ERP) is the sum of the output of the transmitter power plus the gain of the antenna minus antenna transmission losses.

[19] FCC §90.205 rules: http://www.ecfr.gov/cgi-bin/text-idx?SID=fba0b02f1dd9b2a7444b690b83778dac&mc=true&node=pt47.5.90&rgn=div5#se47.5.90_1205.

[20] Man-made noise levels in commercial and non-commercial buildings are creating havoc for some VHF radio system operators worldwide. The FCC safe harbor transmitter power limitations and narrowbanding has only compounded the problem in the United States. ADCOMM believes higher signal levels are required in downtown and dense urban areas in order to improve building penetration signal levels and off-set the VHF noise levels. Unfortunately, this problem is only getting worse over time.

1. Gray: mobile only, but less the 50 percent reliability
2. Blue: mobile only, 37 to 63 dBu
3. Green: portable on-street, 63 to 73 dBu
4. Yellow: portable light building, 73 to 81 dBu
5. Red: portable medium commercial buildings, greater than 81 dBu

A legend displaying the signal levels is included with each coverage prediction map.

Talk-out and talk-in coverage prediction maps illustrate the approximate area of outbound coverage from the fixed radio sites to field users (mobile or portable), while talk-in maps illustrate the approximate area of inbound coverage from field users to the fixed radio sites and, correspondingly, to dispatch.

These predictions can be found in Appendix A. Electronic PDF[21] copies of the coverage predictions are also included on the provided USB drive. The coverage predictions are best viewed using Acrobat Reader,[22] as it allows the ability to use the zoom tool to expand the resolution.

Analysis of Radio Coverage Propagation Prediction Maps

The radio coverage predictions are generally consistent with the feedback provided by dispatch, first responders, and spot-check signal measurements.

ADCOMM performed a detailed analysis of the radio propagation coverage prediction maps (coverage maps) for each of the existing and proposed new radio sites. **These coverage maps clearly show a need for additional radio coverage into rural population centers, along transportation routes, forest, and desired wilderness areas in Park County.**

Existing Repeater Sites Coverage Review

ADCOMM developed radio propagation coverage prediction maps for the two existing repeater radio sites, Wilsall Mountain (North Repeater) and Meyers Flats, respectively (Figure 13).

[21] A PDF file is an Adobe Acrobat portable document file format commonly used for universal document exchange.

[22] A free copy of Acrobat Reader can be found at http://www.adobe.com.

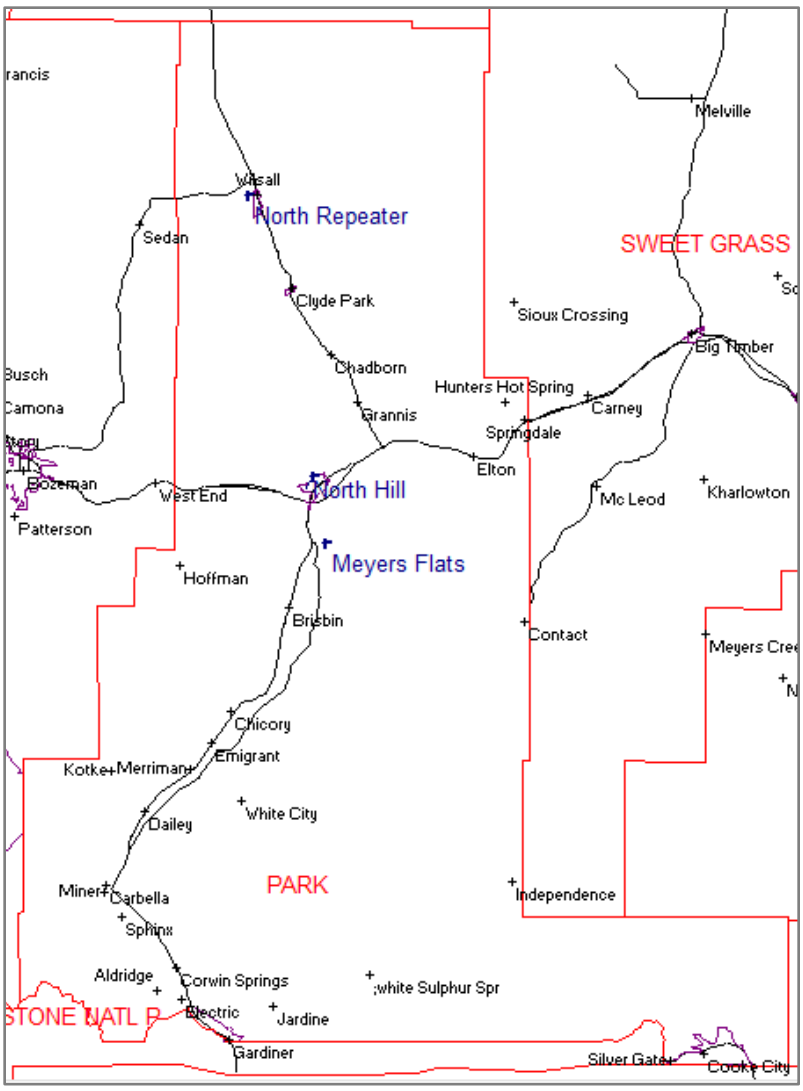


FIGURE 13
Park County Radio Site Locations

- **North Repeater**: This existing site provides primary Fire Dispatch radio coverage for the Wilsall Rural Fire District No. 3 and for some Clyde Park Rural Fire first responders. The North Repeater provides mobile coverage in a wide-area of Park County from approximately north of Clyde Park to the Meagher County line, east to Gallatin County and west to the foothills of the Gallatin National Forest/Crazy Mountains. This site is recommended as a future transmitter and voted receiver site for public safety communications coverage enhancements. The coordinates of the site are 45° 59′ 34.7″ N, 110° 40′ 25.2″ W (NAD83) at an elevation of approximately 5,291 feet AMSL (Figure 14) (see Appendix C, Photograph N-6).

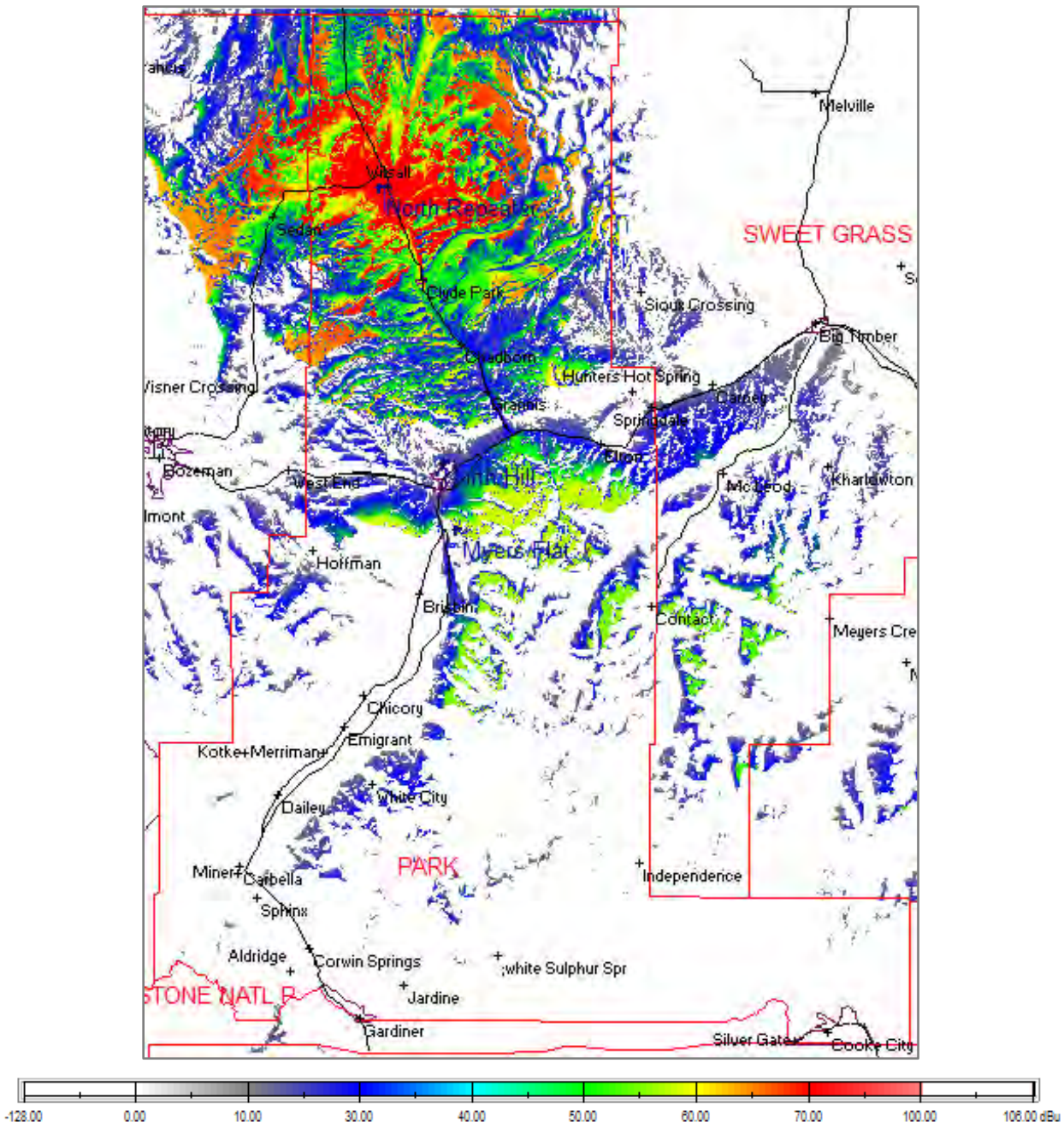


FIGURE 14
North Repeater Talk-Out Coverage Prediction

- **Meyers Flats**: This existing site is considered the main radio site for Park County and provides primary countywide Law and Fire Dispatch radio coverage for all fire departments except the Wilsall Rural Fire District No. 3 and some Clyde Park Rural Fire first responders. Meyers Flats provides significant mobile coverage in a wide-area of Park County from approximately north of Clyde Park to the Meagher County line, east to Gallatin County and west to the foothills of the Gallatin National Forest/Crazy Mountains. This site is recommended as a future transmitter and voted receiver site for public safety communications

coverage enhancements. The coordinates of the site are 45° 35′ 51.1″ N, 110° 32′ 48.9″ W (NAD83) at an elevation of approximately 6,518 feet AMSL (Figure 15).

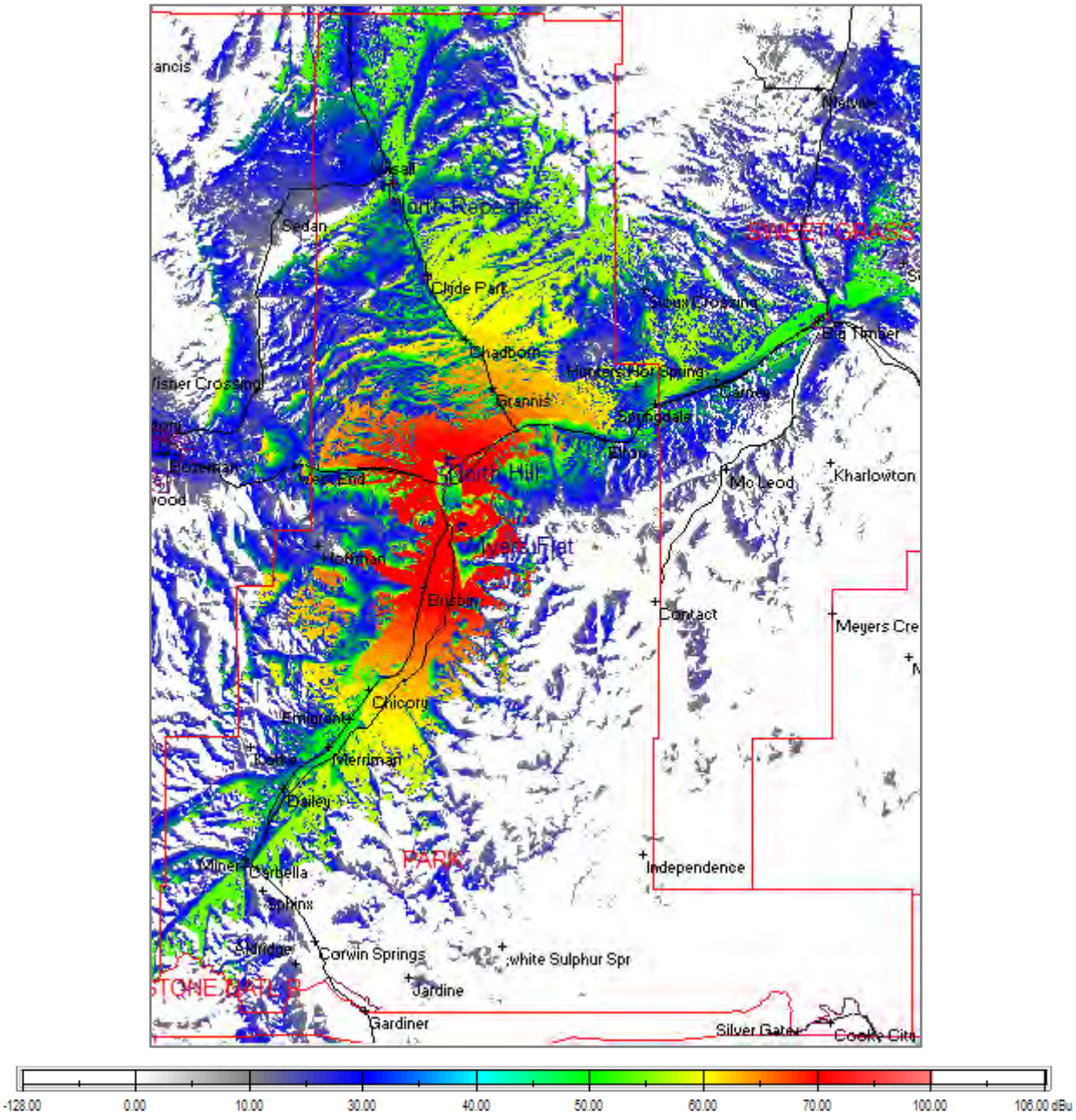


FIGURE 15
Meyers Flats Repeater Talk-Out Coverage Prediction

Existing Control Station and & Base Station Site Coverage Review

ADCOMM developed radio propagation coverage prediction maps for the North Hill control station and base station site. Additional coverage maps are included in Appendix A.

- **North Hill**: This existing radio site is primarily used today as a Law and Fire VHF control station location that allows the Dispatch Center to communicate directly with Wilsall

Mountain (North Repeater), as a backup dispatch base station operating on simplex channels in the event the Meyers Flats repeaters or microwave goes down and for interoperability on State of Montana common channels. This site is underutilized and is recommended as a future transmitter and voted receiver site for public safety communications coverage enhancements in Livingston. The coordinates of the site are 45° 40′ 25.9″ N, 110° 34′ 02.9″ W (NAD83) at an elevation of approximately 4,890 feet AMSL (Figure 16) (see Appendix C, Photograph NH-2).

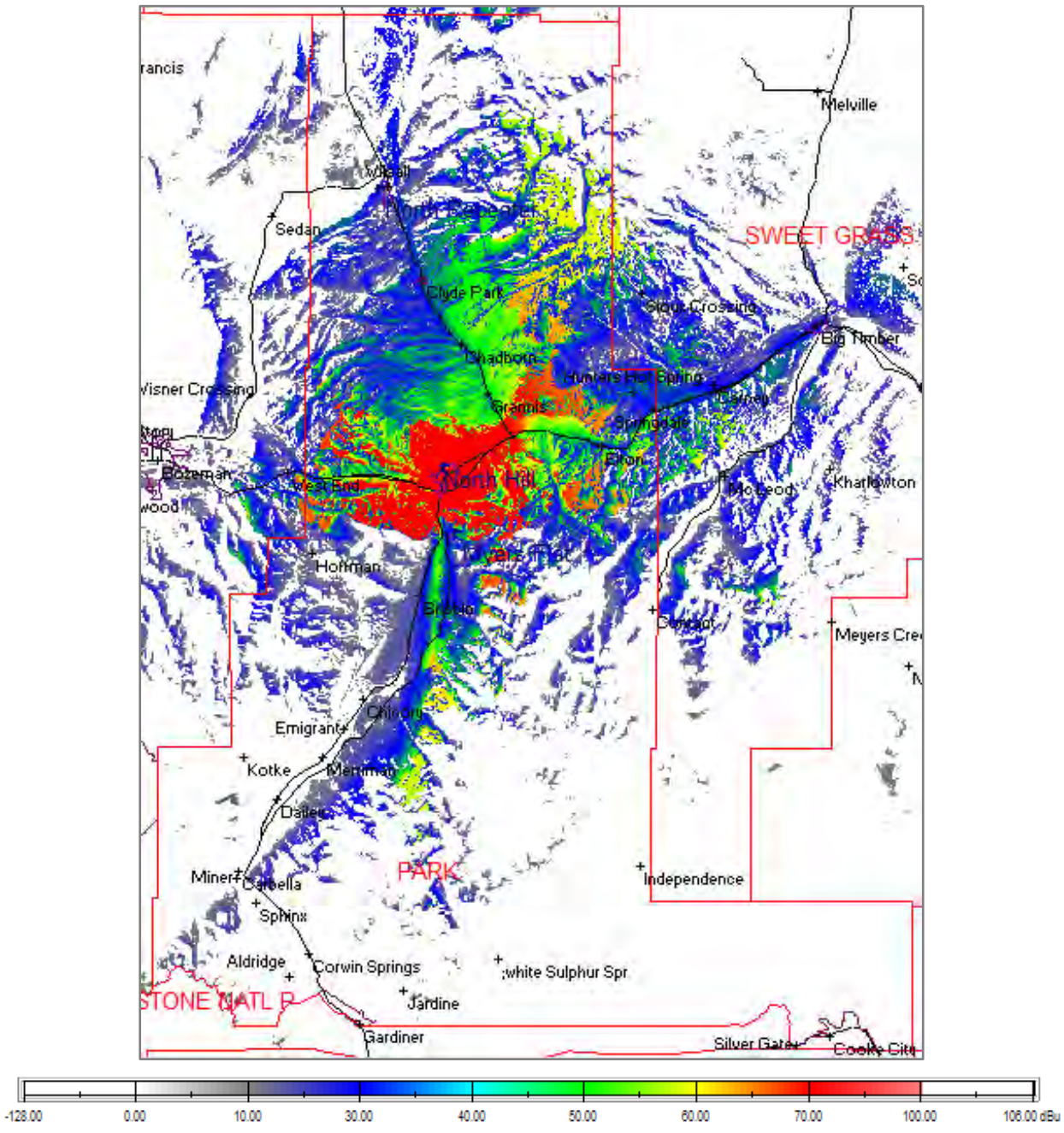


FIGURE 16
North Hill Base Station Talk-Out Coverage Prediction

City of Livingston Detailed Coverage Review

During the interviews with dispatchers and first responders, ADCOMM was told about multiple poor radio coverage locations within the geopolitical boundaries of Livingston. Many of these locations include poor in-building portable radio complaints.

ADCOMM visited a cross sampling of these locations during and after the law enforcement ride-alongs in order to ascertain the radio coverage issues. Early in the interview process ADCOMM questioned the performance of the Meyers Flats repeaters due to the signal quality issues in the southern portion of Livingston. While researching the coverage complaints, ADCOMM determined that the tower identified by first responders as "our tower" on Meyers Flats radio site was actually a cellular tower site on a ridge between the actual Meyers Flats public safety radio site and Livingston.

Preliminary coverage predictions, field signal level measurements and photographs from North Hill and the roof of the 9-1-1 Center confirmed that Meyers Flats is terrain blocked to a significant portion of Livingston.

Figure 17 below, taken from the North Hill radio site, illustrates the location of the cellular site (red arrow) and the ridgeline (red dotted traced line) of the closest prominent tower location seen around Livingston. The Meyers Flats public safety tower (blue arrow) and ridgeline location (blue dotted trace line) is approximately 0.8 mile farther south in the distance.

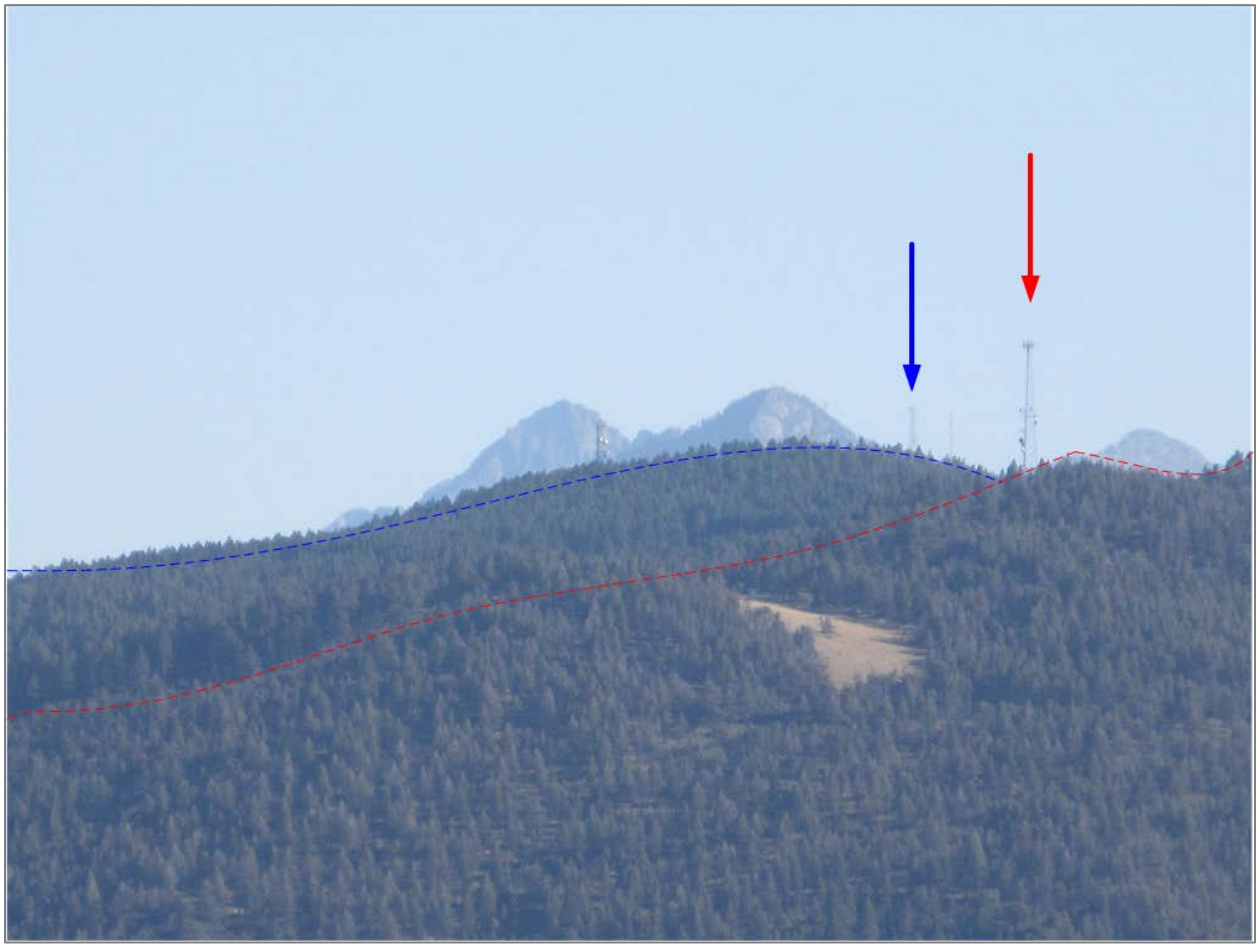


FIGURE 17
Meyers Flats Terrain Blockage Photograph

The Meyers Flats public safety tower is actually located on the highest point on the next ridge behind the cellular tower that is seen in most areas of Livingston. The poor radio coverage in Livingston becomes worse as a first responder travels south towards I-90 due to the terrain blockage. The terrain blockage signals from Meyers Flats start to clear all obstructions at approximately U.S. Highway 89 past SR 540.

The following aerial photograph (Figure 18) provides an overhead view of the cell site and Meyers Flats in relation to Livingston.

FIGURE 18
Aerial View of Livingston, Cell Site and Meyers Flats Site

The following coverage prediction map (Figure 19) shows a much lower than expected signal level for a VHF radio transmitter located approximately 4.6 miles away from Livingston. The areas shown in red represents the desired signal level of 69 dBu or greater talk-out performance to a portable radio inside a medium commercial building. The area shown within the white box is a much lower portable on-street coverage signal level between 51 to 61 dBu. Signal levels of 69 dBu or greater must be provided into the population center of Livingston in order to provide in-building VHF public safety radio communications.

ADCOMM recommends utilizing the existing North Hill site as a future repeater site to mitigate law and fire dispatch talk-out and talk-in radio coverage issues in Livingston. Detailed recommendations are included in the *Final System Recommendations* section of this report.

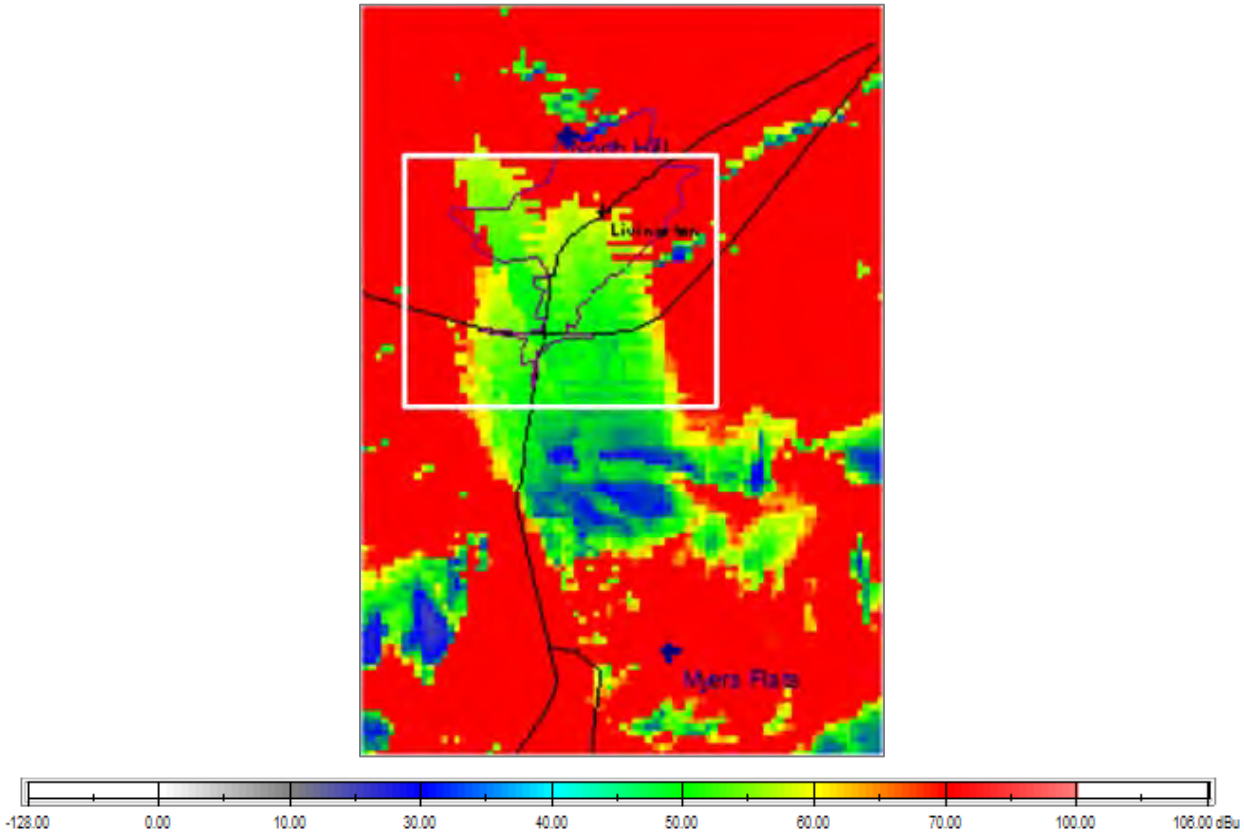


FIGURE 19
City of Livingston Meyers Flats Terrain Blockage Signal Impact

Gap Analysis

9-1-1 Dispatch Center

Gap: There are no collocated VHF control or base stations that can communicate directly with the Meyers Flats repeaters. In the event of a microwave and telephone line outage, Livingston Park County 9-1-1's Dispatch Center would be off the air beyond the use of handheld radios. VHF control stations should be made available at each console position.

Meyers Flats Radio Site

Gap: Law Dispatch and Park County SO repeaters experience receiver desense. This limits the uplink coverage of both channels.

Gap: The transmitter combiner and receiver multicoupler have connectors that easily come apart. In the event this occurs, all repeater operations can be rendered useless, which would cease dispatch and user-to-user communications.

North Hill Radio Site

Gap: The condition of the batteries providing backup power is questionable. In the event of site power failure, the surrounding area would lose repeated coverage. Batteries should be replaced and a yearly battery preventive maintenance schedule should be implemented.

Gap: The Fire and Law base stations do not operate in narrowband, which can cause distorted audio and is not compliant with FCC rules.

Wilsall Mountain — North Repeater Radio Site

Gap: The condition of the batteries providing backup power is questionable. In the event of site power failure, the surrounding area would lose repeated coverage. Batteries should be replaced and a yearly battery preventive maintenance schedule should be implemented.

Technology Review

Executive Summary

As part of the Park County 9-1-1 Radio System Study project (the "project"), ADCOMM evaluated a number of radio technologies and the viability of each with regards to an upgraded radio system for the county. This report details ADCOMM's findings.

Many two-way land-mobile radio (LMR) technologies and options exist today, some of which might be appropriate for use in an updated radio system for Park County while others are not. In general, the primary technologies and options can be categorized by frequency band, system architecture, and air interface technology.

The primary public safety LMR frequency band options are low-band VHF (30 to 50 MHz), high-band VHF (150 to 174 MHz), UHF (450 to 470 MHz), 700 MHz, and 800 MHz, with each band having its own advantages and disadvantages. Since all users in the county currently use VHF, it would be advantageous for a new system to also be on VHF so at least some existing mobile and portable radio equipment could be reused. Unfortunately, it is most difficult to find usable new frequencies in the VHF band. It may be possible to find some number of additional VHF channels to be licensed, but there may not be sufficient channels to meet the needs of users in the county. The VHF frequency congestion is made worse by the use of VHF by the State of Montana for their trunked radio system and the extensive use of the "color" VHF channels statewide for interoperability.

Numerous system architecture technologies are available, including standalone base stations and repeaters, receiver voting, transmitter steering, multicast, simulcast, trunking, and various combinations thereof. Given the size of Park County, and to maximize frequency-use efficiency while reducing operational complexity, ADCOMM believes that simulcast technology (in conjunction with receiver voting) makes the most sense for the long-term system goal.

Further, with the relatively small number of channels needed, a conventional (non-trunked) system would likely be most cost-effective in meeting the needs of users in the county. Either analog FM or Project 25 (P25) digital could be used with such a conventional system. For channels where encryption is desired, P25 is recommended. However, at this time, using an encrypted dispatch channel was not indicated as a requirement.

If a transition to P25 is undertaken, consideration must be given to interoperability and mutual aid, since the vast majority of surrounding counties and other mutual aid agencies would continue to operate on VHF analog.

In addition to the LMR system itself, there are various technology options available for providing radio site connectivity, or *backhaul*, such as microwave, fiber, telephone lines, radio frequency (RF) links, and control stations. To support a simulcast system, highly reliable and stable connectivity is needed. Wherever possible, ADCOMM recommends using licensed microwave systems; however, fiber and telephone company T1 circuits may also be viable in some circumstances.

To augment the existing or updated LMR system, agencies may also wish to consider limited use of Bluetooth wireless microphones for their mobile radios, which can provide limited

"outside the vehicle" radio coverage where only mobile service is available. Such microphones have limitations, but they can be effective when used properly.

At this time, ADCOMM does not believe the *FirstNet* public safety broadband network will be a viable option for use in Park County, particularly for push-to-talk (PTT) voice, any time in the foreseeable future.

Introduction

Technology Review

The goal of the Technology Review is to provide Park County with an overview of current and future technologies in voice radio systems, along with an evaluation of each technology's applicability in the County's circumstance. The Technology Review is intended to give Park County decision makers a firm foundation in the technologies that are available so informed decisions can be made in the Strategic Direction portion of the project. Options for frequency bands, system architectures/access configurations, and modulation modes are discussed. In addition, brief discussions of backhaul technology options and other technology considerations are included.

Overview

Many different two-way radio technologies and options exist today, some of which would be appropriate for use in Park County while others are not generally recommended. For the LMR system that users access directly with their radios, these technologies and options can be categorized by frequency band, system architecture (including distribution configuration and system access configuration), and modulation mode or air interface technology. Each of these categories are described and examined in relation to the Park County radio project in the next sections of this report.

In addition to the LMR system itself, there is a variety of technology options available for providing radio site connectivity (backhaul), such as microwave, RF links, control stations, etc. A description and evaluation of each of the primary connectivity methods are also included.

Lastly, there are other technologies available that can be used to augment a standalone LMR system, such as vehicular repeaters, alphanumeric paging, and perhaps at some point in the future even a potential replacement of private LMR systems altogether by the First Responder Network Authority ("FirstNet"). A description of these technologies and their viability is included as well.

LMR System Technologies and Options

Frequency Bands

Numerous frequency bands have been assigned by the Federal Communications Commission (FCC) for LMR use. Each of the bands detailed below has frequencies allocated for public safety use, as would be appropriate for Gallatin County's radio system.

Low-Band VHF

The low-band VHF frequency band, commonly referred to simply as "low band," consists of spectrum in the 30 to 50 MHz range. Although it can provide better coverage in areas with hilly

and mountainous terrain compared to other frequency bands, there are significant issues related to low band. Because of these issues, low band is no longer commonly in use.

One issue with low band is that it is significantly more susceptible to propagation "skip" than the other frequency bands. Under *skip* conditions, co-channel users can be heard and cause interference from distances of hundreds or even thousands of miles. Skip is often unpredictable and little can be done to control it.

Another issue with low band is that antennas and filtering equipment are much larger than with other bands. This can impact tower loading as well as equipment shelter space utilization. For example, low band cavity filters can be 7 to 8 feet tall, whereas a VHF high-band cavity might be 3 feet tall.

Further, because of the limited demand for low-band equipment, there is a limited number of suppliers of low-band fixed infrastructure equipment (i.e., repeaters, base stations, antennas, filters, etc.) as well as subscriber equipment (i.e., mobile and portable radios).

If low band were to be used by Park County, all radio infrastructure and subscriber equipment would need to be replaced. In addition, interoperability with surrounding agencies using other frequency bands (most commonly *high-band* VHF) would be impeded with a change to low band.

Because of the significant number of downsides, **ADCOMM does not recommend Park County pursue a low-band solution.**

High-Band VHF

The LMR high-band VHF frequency band, commonly referred to simply as "VHF," consists of spectrum in the 150 to 174 MHz range. Many public safety, as well as industrial/business systems, use VHF, including virtually all public safety users in Park County. Although it does not provide coverage as effectively as low band in hilly and mountainous areas, VHF does provide somewhat better non-line-of-sight coverage than UHF, 700 MHz, and 800 MHz.

While not totally immune from it, VHF frequencies suffer far less from skip than low band. On the other hand, in all but the most remote locations, the VHF band suffers from a high noise floor, which has a direct impact on radio system performance, effectively reducing usable range or coverage.

Another one of the more significant issues with VHF is limited frequency availability. This is partly due to the band's popularity, but it is further impacted by the lack of an efficient *band plan*.[23] For instance, it is possible to have one VHF frequency be used as a repeater transmit ("output") frequency by one licensee and as a mobile transmit/repeater receive ("input") frequency by another licensee some distance away, potentially creating interference between the two systems.

In most areas of the country, it is difficult at best—or not feasible at all—to deploy a *trunked* radio system at VHF due to the limited frequency availability and the co-channel spacing

[23] FCC band plans define how the frequencies in a particular band may be used, particularly in regard to *base transmit* and *mobile transmit* use. Efficient band plans group base transmit frequencies in one part of a band and mobile transmit frequencies in another part of a band and include frequency separation between the two. Inefficient band plans allow for more haphazard use of frequencies within a band.

requirements for a trunked system. Although the Montana "state" trunked VHF radio system has sites in and around Park County, expansion of this system in Park County with additional frequencies may not be possible due to the *exclusive-use* frequency coordination requirements for a trunked system. Even for a conventional (non-trunked) system, depending on how many total channels are desired, there may not be a sufficient number of VHF frequencies available to meet Park County's needs.

Because agencies in Park County already use VHF, depending on whether the upgraded system uses analog or P25 digital, it may be possible to reuse many of the existing mobile and portable radios, thus reducing the overall project cost. Further, interoperability with surrounding agencies that continue to use VHF would be unaffected. Due to its popularity, VHF infrastructure and subscriber equipment is readily available from numerous manufacturers.

Because of the existing inventory of subscriber units, favorable propagation characteristics, and interoperability, **ADCOMM believes using VHF is a viable option for Park County but only if a sufficient number of frequencies can be licensed.**

UHF

The UHF frequency band for LMR operations consists of spectrum in the 450 to 470 MHz range. Many public safety and industrial/business systems use UHF, although somewhat less so in more rural areas including Montana. Because they are higher frequencies, UHF does not generally propagate as far as VHF or low band. As a result, in some cases a greater number of sites may be required to provide comparable coverage. On the other hand, the noise floor at UHF tends to be lower than at VHF, which can make up for some or all of the reduced coverage. Further, due to its shorter wavelength, in-building coverage at UHF is often better than at VHF.

As with VHF, UHF infrastructure and subscriber equipment is readily available from numerous manufacturers. In addition, particularly in more rural areas, there is better availability of UHF frequencies due to its lower popularity as well as having an efficient band plan. In some areas around the country, it is still feasible to deploy trunked systems at UHF due to having better frequency availability. There are likely a sufficient number of UHF frequencies available in Gallatin County for an upgraded conventional system or conceivably even a trunked system.

Because Park County does not currently use UHF, all new radios would need to be purchased, significantly increasing overall project costs. Further, since the vast majority of surrounding agencies would still be using VHF, interoperability would be impacted, likely requiring some users to carry multiple radios or more expensive dual-band radios.

ADCOMM believes UHF would not be a good option for Park County because of the cost to replace all of the user equipment.

700 MHz

The 700 MHz *narrowband* LMR frequency band consists of spectrum in the 769 to 775 MHz and 799 to 805 MHz ranges.[24] The 700 MHz band is reserved for use by public safety and governmental entities; there are no industrial/business channels. Compared to the other LMR bands, 700 MHz is the "newest," having been allocated by the FCC to public safety in the early

[24] This does not include the 700 MHz *broadband* spectrum reserved for the nationwide FirstNet public safety long-term evolution (LTE) network.

2000s in conjunction with the subsequent transition to digital broadcast television. All *general-use* channels in the 700 MHz LMR band are required to use digital modulation (e.g., P25); analog is not permitted.

The biggest advantage of the 700 MHz band is frequency availability, with no known current use in Montana. Unfortunately, 700 MHz propagates even shorter distances than UHF. While suitable for many urban and suburban environments, a potentially significant number of additional sites could be required to provide the necessary coverage, particularly in the rural and mountainous areas of Park County.

As with UHF, the purchase of new 700 MHz mobile and portable radios would be required for all agencies. Interoperability with surrounding agencies would also be complicated by a move to 700 MHz.

Because of the greater number of sites required, high subscriber unit replacement costs, and interoperability issues, **ADCOMM does not recommend 700 MHz for Park County.**

800 MHz

The 800 MHz LMR frequency band consists of spectrum in the 806 to 821 MHz and 851 to 866 MHz ranges. Propagation characteristics of 800 MHz are similar to 700 MHz, thus an 800 MHz system would require essentially the same number of sites as a 700 MHz system. In fact, many systems today use a mix of 700 and 800 MHz channels to meet their capacity requirements. Unlike 700 MHz, analog modulation is permitted on 800 MHz channels. Note that there are no manufacturer-supported analog trunked options available (only conventional analog is supported).

The only known 800 MHz public safety system in Montana is operated by the City of Billings. As such, there would be no issue with licensing a sufficient number of 800 MHz channels for a new system in Park County. As with 700 MHz, though, additional sites would be required to provide comparable coverage to VHF or even UHF, thus increasing system costs.

Since there are no 800 MHz radios in use today, new mobile and portable radios would be needed for all agencies. In addition, interoperability with surrounding agencies would be impeded with a shift to 800 MHz.

As with 700 MHz, because of the greater number of sites required, high subscriber replacement costs, and interoperability issues, **ADCOMM does not recommend 800 MHz for Park County.**

System Architectures

Radio system architectures can be broken into two primary access configurations: *conventional* and *trunked*. The key difference between these two configurations is how frequencies are assigned to users and their associated transmissions. In addition, there are various technologies available for providing wide-area coverage, including receiver voting, simulcast, multicast, and transmitter-steering, which are often used in conjunction with both conventional and trunked systems. This section describes each of these technologies, their associated advantages and disadvantages, and potential applicability to Park County.

Conventional Base Station Systems

Conventional base station simplex radio systems are the simplest form of VHF and UHF *frequency modulation* (FM)[25] LMR communications technology today and have stayed relatively the same since the 1950s. Base station, mobile, and portable radio communication range are all limited by line-of-sight and signal propagation. Simplex systems use one frequency per channel (see Figure 20). Conventional base stations are not used on any of the main Park County dispatch channels.

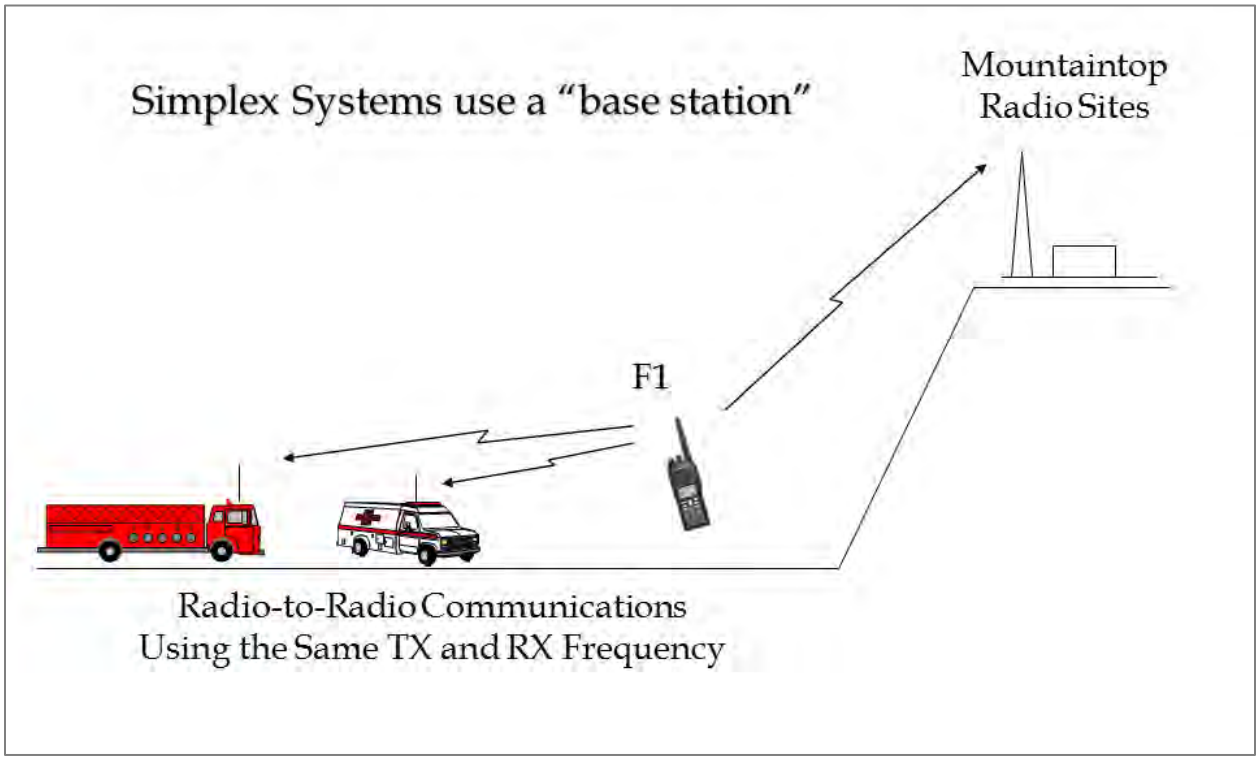


FIGURE 20
Simplex Base Station System

Advantages

- The use of a single base station is the least-cost technology solution to provide limited area communications coverage.

Disadvantages

- Single conventional base stations on mountaintops require microwave or telephone control circuits.
- Multiple conventional base stations must be strategically located throughout the desired service areas.
- The use of a single conventional base station may not provide the necessary radio coverage required in the desired service areas (see Figure 21).
- A mobile or portable radio user can interfere with dispatcher transmissions.

[25] Frequency modulation is a method of transmitting information on an analog channel by varying the carrier frequency.

- Multiple conventional base stations on the same frequencies using different CTCSS require dispatcher and user training so that the correct base station is used in the specified operating area. As an example, it is possible for a radio user to respond back to a dispatcher on a base station that does not have overlapping coverage. This condition may cause missed communications and confusion.

Due to their limited capability and coverage, **ADCOMM does not recommend Park County use conventional base stations for its system upgrade.**

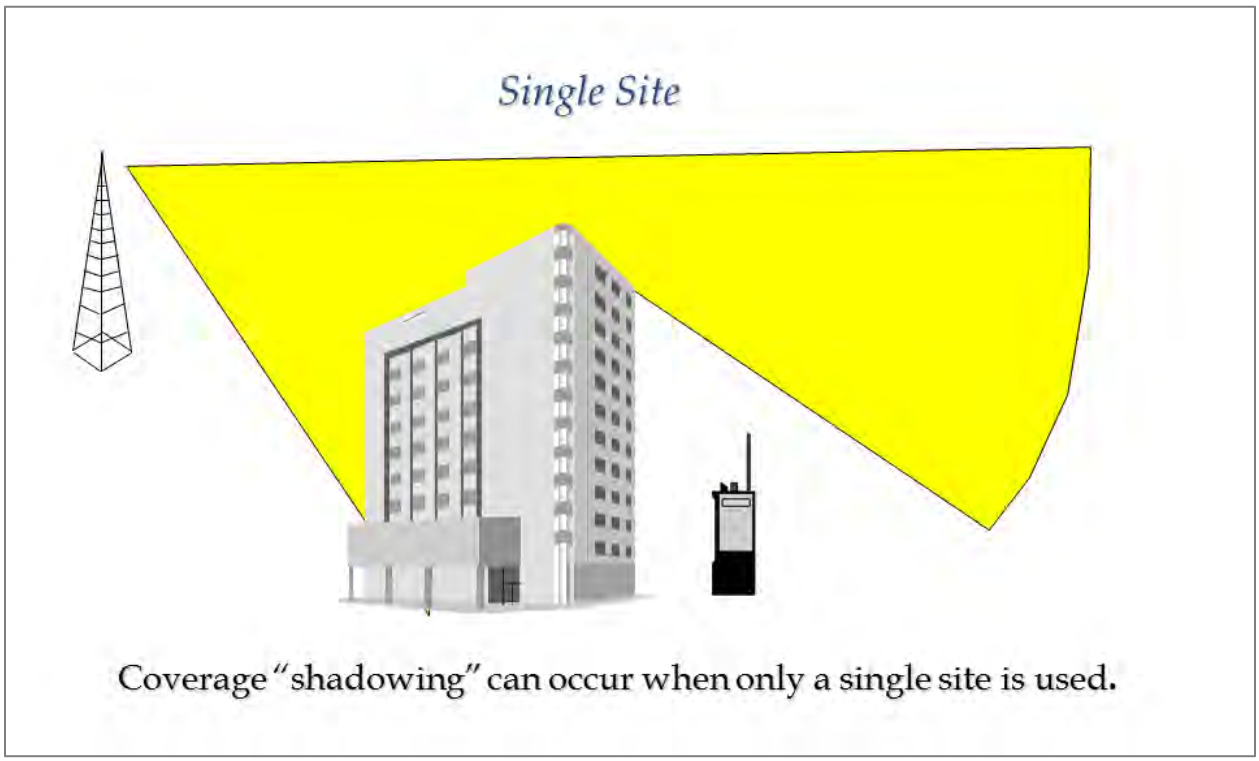


FIGURE 21
Single-Site Coverage

Conventional Repeater Systems

Conventional repeater systems extend the range of mobile and portable radios by receiving a low power signal, amplifying the signal, and automatically retransmitting it at a higher power level. Repeaters are often located on mountaintops or buildings to increase the radio coverage. Repeater systems use two frequencies per channel (see Figure 22). The vast majority of the existing radio systems in Park County employ conventional repeaters.

Advantages

- The use of a single conventional repeater is the least-cost technology solution to provide limited area communications coverage while allowing a dispatcher and other radio users to hear both sides of a conversation at the same signal strength.
- Single conventional repeaters can be standalone devices that do not require microwave or telephone control circuits.

- Multiple conventional repeaters can be strategically located throughout the desired service areas.

Disadvantages

- The use of a single conventional repeater may not provide the necessary radio coverage required in the desired coverage area (see Figure 21).
- A mobile or portable radio user can interfere with dispatcher transmissions.
- Multiple conventional repeaters on the same channels require dispatcher and user training so that the correct repeater is used in the desired coverage area. As an example, it is possible for a radio user to respond back to a dispatcher or other radio user on a repeater that does not have overlapping coverage. This condition may cause missed communications and confusion.

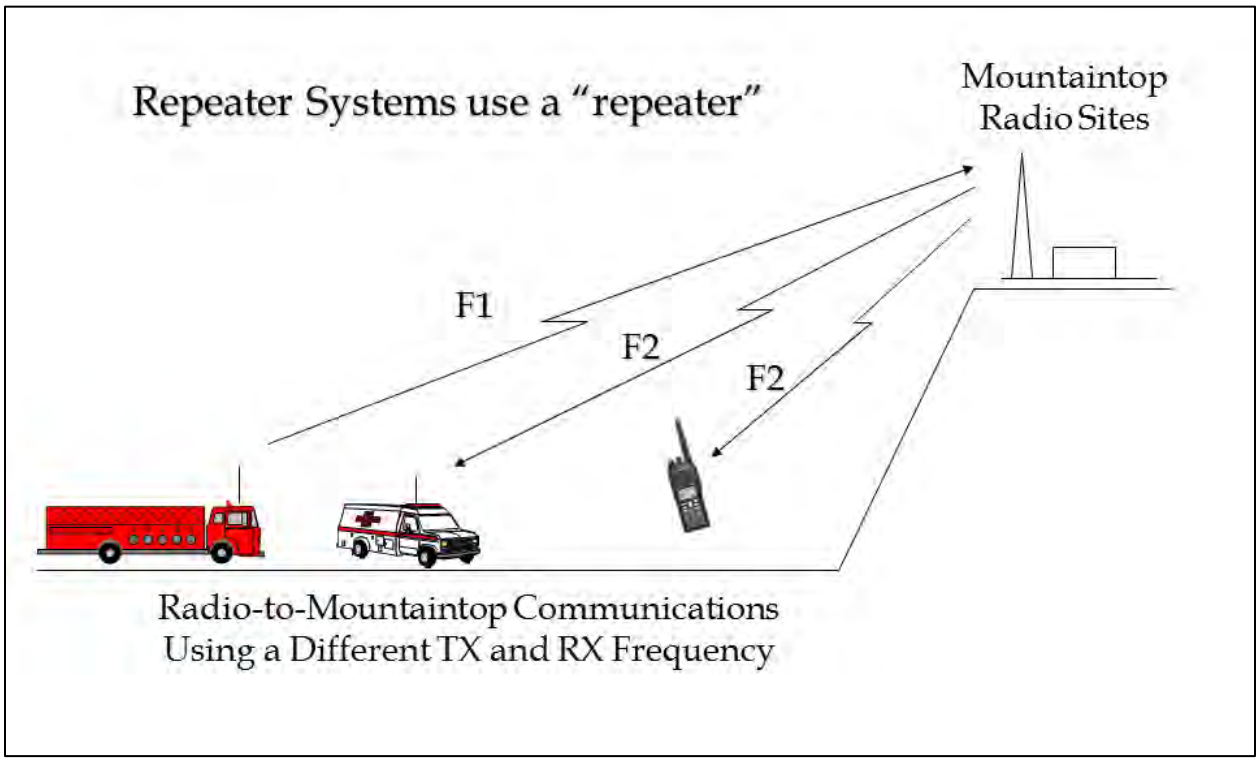


FIGURE 22
Repeater System

Although not as ideal in some situations as other technologies, such as simulcast or multicast, given their affordability and relative ease of deployment, **ADCOMM believes the strategic use of conventional repeaters continues to be appropriate for addressing portions of Park County's communication needs**, particularly tactical uses and in very rural areas with relatively low usage.

Voting Receiver Systems

A voting receiver system has dedicated radio receivers that are strategically located so one or more of the receivers will receive a good quality signal from a mobile or portable radio transmitting from anywhere in a desired service area. The output of the receivers is connected to a

centrally located device called a voting comparator (or "voter"). Because the same signal may reach several voting receivers at once, the comparator continuously compares the received signals, selects the receiver with the best audio quality, and then routes the receive audio to a dispatcher and/or repeater transmitter. The selection and change-over from one receiver to another is rapid enough to prevent loss of any words. Voting receivers are normally co-located with repeater transmitters or can be located as a standalone receiver in critical coverage areas (see Figure 23).

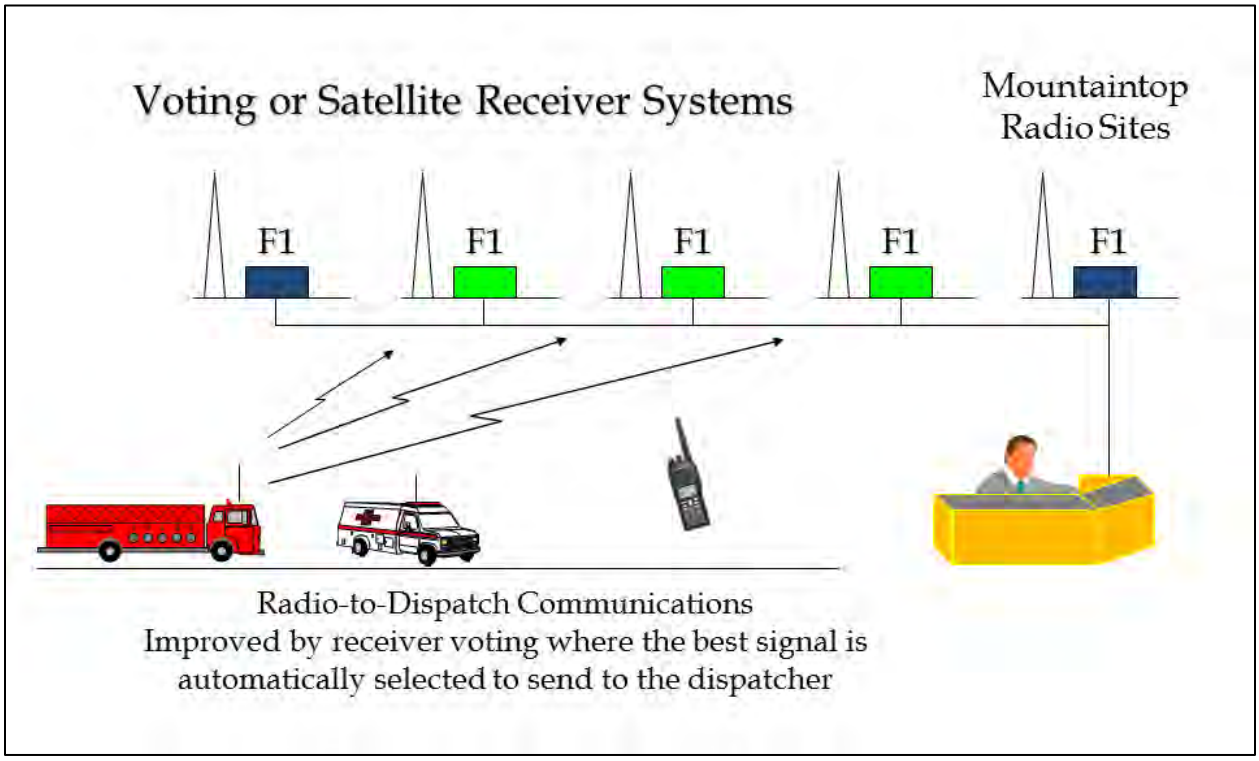


FIGURE 23
Voting Receiver System

It is common for a low-power portable radio to hear a high-power repeater yet be unable to talk to a dispatcher or other radio user on a repeater system because of a weak talk-in signal. A repeater system with numerous voting receivers can greatly improve portable radio communications in the specified operating area of the transmitter.

There are no voting receiver systems currently in use in Park County.

Advantages

- The benefit of a voting receiver system is to extend the talk-in or talk-back range from low power radios in the field to the dispatcher and other radio users on the repeater system.
- Radio users do not need to remember to switch between radio sites to communicate with a dispatcher or other radio user when using a single-channel voted radio system.

Disadvantages

- A dedicated communications link must connect the dispatch center with each radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance and operating costs.

With their effectiveness at improving talk-in coverage from field users and simplifying radio and dispatch operations, **ADCOMM believes the use of voting receivers would be an extremely beneficial part of any radio system upgrade for Park County.**

Dispatcher-Controlled Repeater Transmitter Steering Systems

A dispatcher-controlled transmitter steering system can be used in conjunction with a receiver voting system. One of the methods of preventing interference with multiple repeaters sharing the same channel is to allow only one repeater transmitter site to be active at one time. This can be controlled by the dispatcher via a dispatch console (see Figure 24).

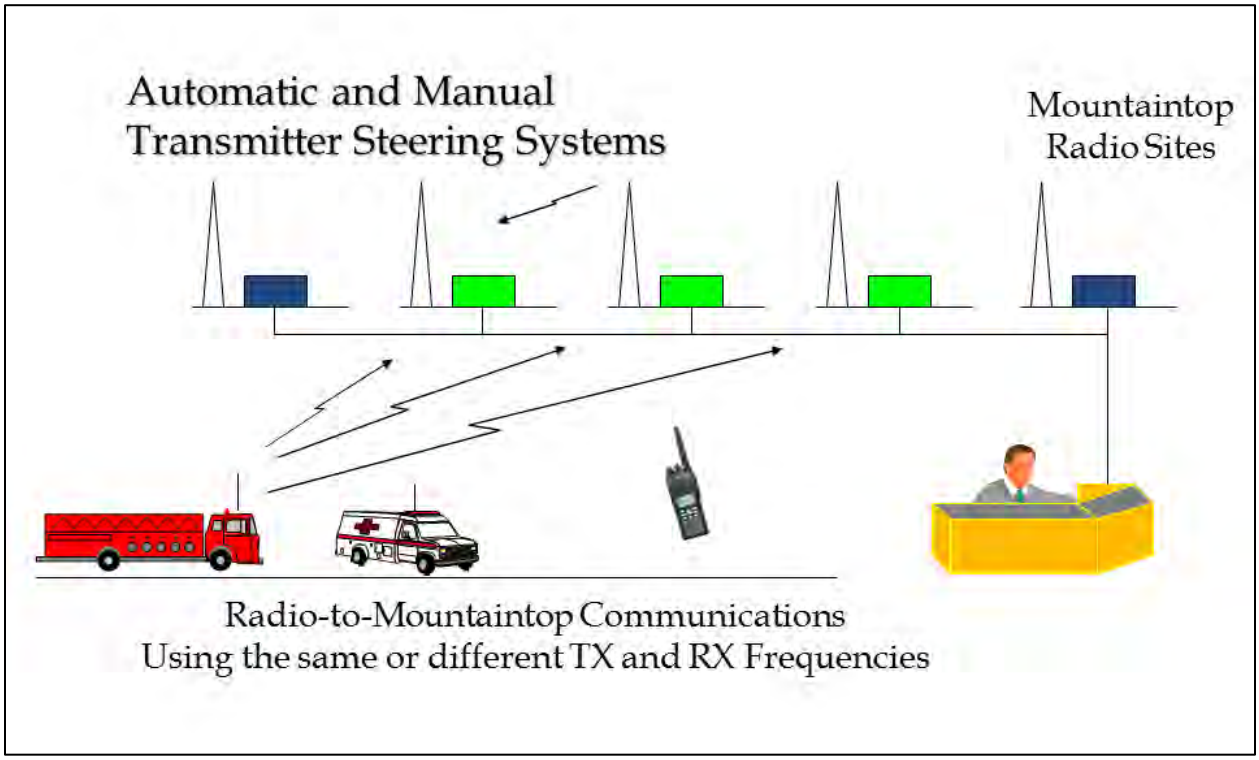


FIGURE 24
Automatic/Manual Transmitter Steering System

Currently, Park County is not using a transmitter steered system. Dispatchers can select individual sites to transmit on but there is no associated receiver voting system.

Advantages

- Can eliminate the possibility of two users keying up two different repeaters at the same time causing interference between repeaters.
- The dispatcher can select the best repeater transmitter to a single or group of mobile or portable radio users.
- Less expensive than other advanced wide-area coverage systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each remote radio site.

- One repeater transmitter cannot provide the radio coverage throughout the desired service area. There may be times when two units that need to intercommunicate are separated over enough distance they cannot hear each other because the single site does not provide adequate coverage.
- The dispatcher must know the coverage area of each selectable repeater transmitter and the location of the field unit.
- Dispatchers performing other duties may be unable to switch the transmitter between the sites to provide the necessary radio coverage.
- As the dispatcher switches the active transmitter between sites, some radio users may miss important communications because the selected transmitter may be weak in their area.

Due to the number of sites that are required to effectively cover Park County or even just the northern portion of the county, expanded use of transmitter steering systems would generally only serve to increase operational complexity while not always being effective in providing the necessary coverage. However, while **ADCOMM generally does not recommend manual transmitter steering systems as a primary system architecture it can be used as a transition technology on the path to simulcast for Park County's updated radio system.** It also may be an effective technology for the fire users since they generally have a smaller area of operation than does law enforcement.

Automatic Transmitter Steering Systems

An automatic transmitter steering system is normally used in conjunction with a receiver voting system. It operates on the theory the best transmitter site to reach a particular mobile or portable radio user is also the last site that received the best signal. When a mobile user calls a dispatcher, the voting system comparator selects the best audio quality receiver. On the assumption the dispatcher will immediately answer the mobile radio user that just called, the transmitter steering system remembers the last receiver the voting comparator selected and automatically selects the transmitter co-located with the voting receiver site. If standalone receivers are deployed, the transmitter steering controller system can be preprogrammed to use a transmitter for a group of receivers in a specified operating area. A default transmitter location can also be selected for an initial "first of day" dispatch (see Figure 25).

Advantages

- Transmitter steering is a relatively inexpensive way to have the benefits of multiple transmitter sites.
- Less expensive than other advanced wide-area coverage systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each radio site.
- The comparator could make the wrong decision because of a weak signal received simultaneously by multiple receivers. This could cause the faraway transmitter to be automatically selected and in turn could cause the response from a dispatcher or other radio users to be unreadable.
- Another condition that could cause the wrong automatic transmitter selection is when a second radio user calls a dispatcher just before the dispatcher responds to the first radio

user. The first radio user may not hear the dispatcher because of a faraway transmitter being selected by the last transmission of the second radio user.

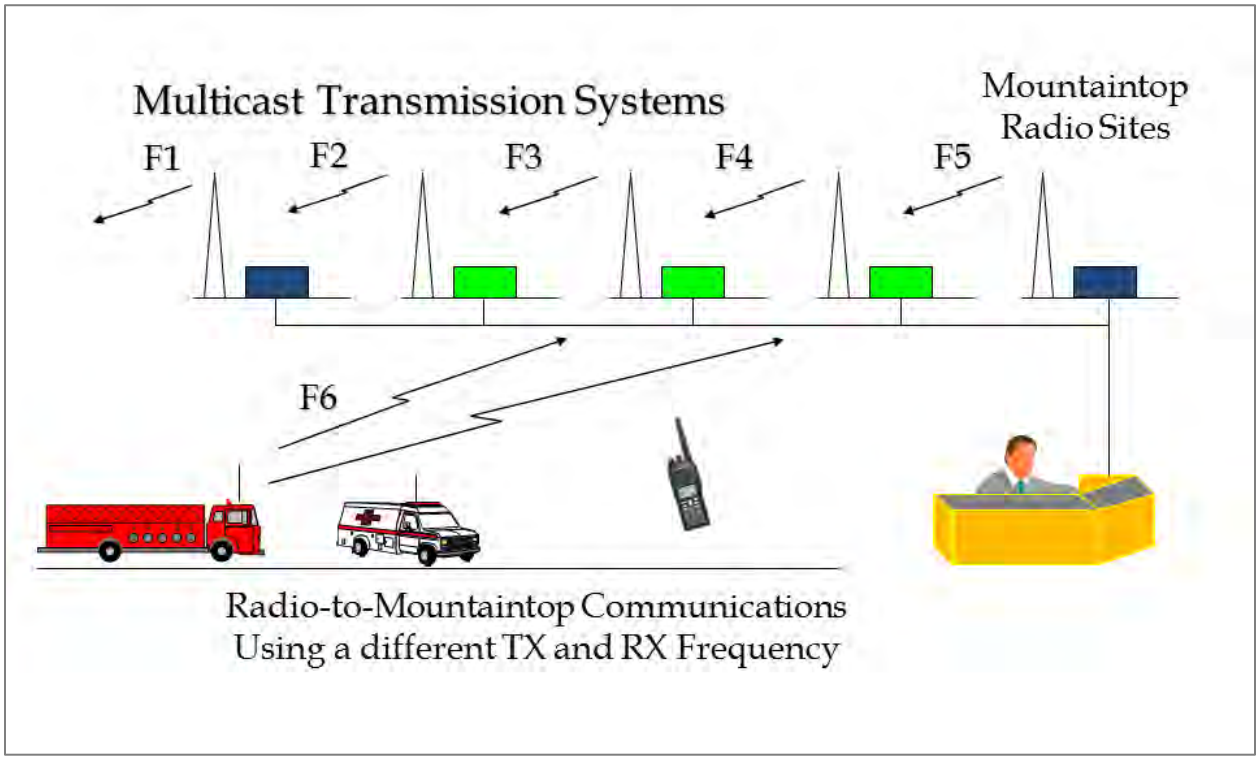


FIGURE 25
Multicast Transmission System

Transmitter steering systems can be made to work successfully in the right application. A typical application where it will work the best is an area where there is significant transmitter overlap and most of the communications are initiated by the mobile unit to the dispatch center.

Due to the limited number and placement of sites required to effectively cover Park County, expanded use of transmitter steering systems could provide additional operational flexibility while incurring some additional operational complexity. As such, **ADCOMM recommends transmitter steering systems as a transition system architecture for Park County's updated radio system.** Again, depending on the availability of frequencies, automatic transmitter steering could potentially be an option for covering Park County, albeit a less preferred option than simulcast or multicast.

Multicast Transmission Systems

Multicast technology can be used when an abundant number of radio frequencies are available. Multicast is a wide-area radio system configuration using simultaneous transmissions of identical audio on separate frequencies from each transmitter site. Each transmitter is equipped with a receiver, and a receiver voting system is then used to select the best received signal. Multicast technology is a spectrum-*inefficient* technology (see Figure 25).

Multicast is not currently used in Park County.

Advantages

- Dispatchers do not need to worry about transmitter selection.
- Less expensive than simulcast technology.

Disadvantages

- Radio users need to switch channels as they traverse the various radio coverage areas.
- A dedicated communications link must connect the dispatch center with each repeater radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance.

Practically, there may be an insufficient number of VHF frequencies available to deploy multicast in Park County, except perhaps in the southern part of the county. However, frequency availability will not be known until additional frequency engineering is accomplished as part of the actual system design, not part of this contract. As such, **ADCOMM believes multicast may be a practical option for Park County.**

Simulcast Transmission Systems

Simulcast technology has been in existence since approximately the 1960s. However, the technology has improved significantly in recent years to the point where the maintenance issues have been reduced to manageable levels. Simulcast technology allows the use of the same frequency to transmit the same information simultaneously from multiple radio sites with overlapping coverage. Simulcast is basically "controlled interference" from multiple transmitters. This is accomplished by having accurate frequency control, audio phase, and amplitude control from the transmitters. A two-way radio system using simulcast technology always uses a receiver voting system. Simulcast uses multiple transmitters usually operating at lower power levels spread throughout the specified service area to improve coverage. Each transmitter is equipped with a receiver, and the receiver voting system is used to select the best received signal (see Figure 26 and Figure 27).

Simulcast technology is a spectrum-*efficient* technology because it allows the use of lower power transmitters thus reducing the amount of signal that travels outside the operational area, and it allows wide areas to be covered by a single frequency. Simulcast is relatively expensive to implement because of the special techniques required. It is used on many public safety systems and virtually all wide-area alphanumeric paging systems, both commercial and private.

To a dispatcher or radio user in the field, simulcast technology acts like a single transmitter with wide-area coverage. Unlike manual or automatic transmitter steering, no dispatcher or radio user intervention is required.

Currently, in Park County no simulcast is used.

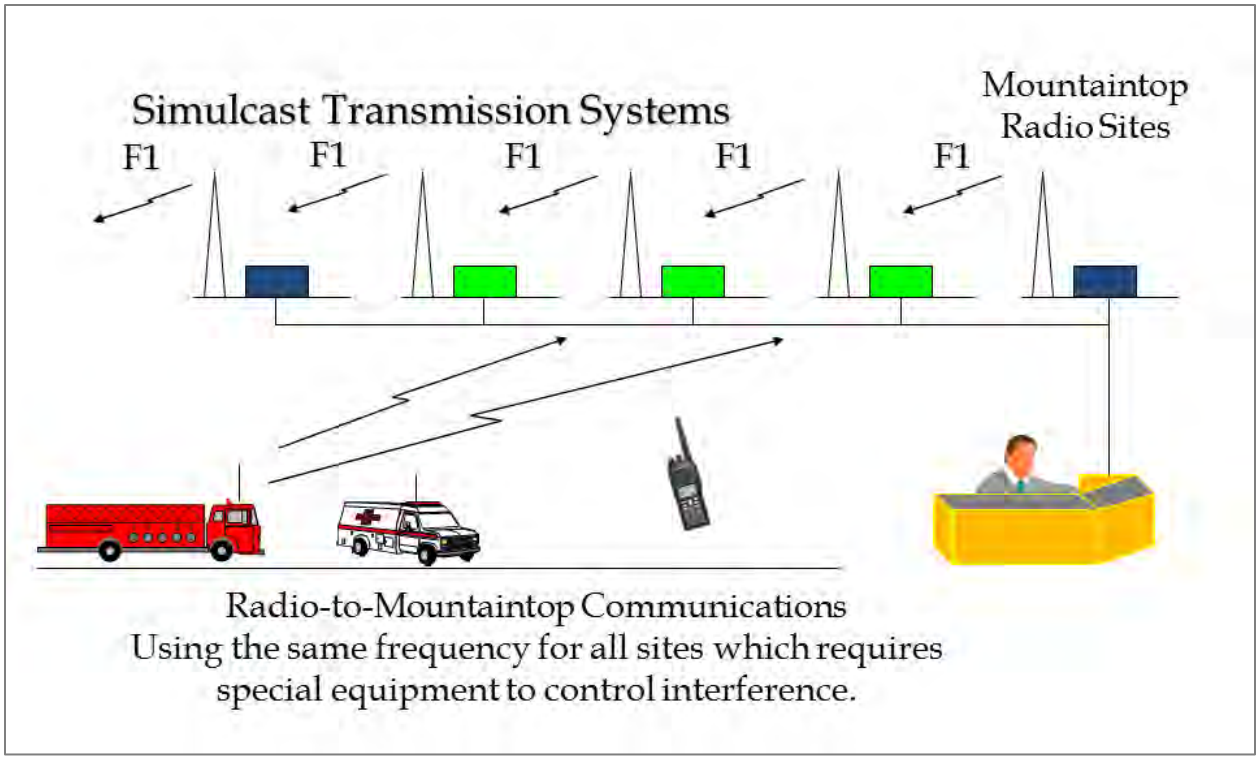


FIGURE 26
Simulcast Transmission System

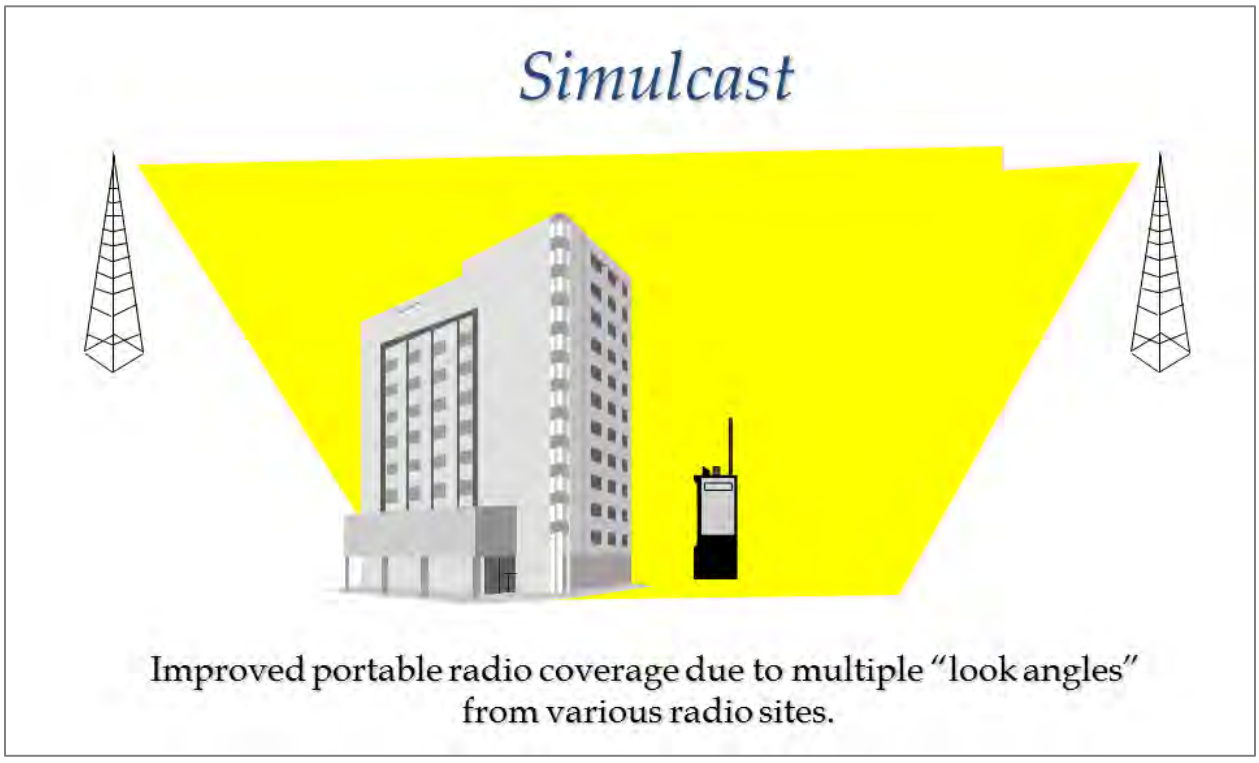


FIGURE 27
Simulcast Coverage

Advantages

- Dispatchers and radio users do not need to worry about transmitter selection.
- If desired, a single radio channel can have countywide radio coverage.

Disadvantages

- A dedicated communications link must connect the dispatch center with each repeater radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance.

Due to limited frequency availability, the number of channels desired, and the dramatically improved coverage and ease of user operation, **ADCOMM believes simulcast technology is preferred as the final system solution for Park County's upgraded radio system.**

Trunked Radio Systems

Trunked technology was originally developed in the late 1800s and early 1900s as the basis of the public-switched telephone network (PSTN) still used today (circuit switched, not IP[26] based). Trunked radio technology has only been around since approximately 1980, facilitated primarily by the development and use of small and inexpensive microprocessors in mobile radios.

Trunked radio technology is commonly used when a limited number of radio frequencies are available. Trunked technology is spectrum-efficient because trunked systems distribute the radio users among all of the available frequencies automatically. This provides much better utilization of the limited frequency resources as compared to conventional systems, whose channel resources can go unused even when there is a demand for service on other channels. The actual assignment of a frequency is not under the control of the radio user or dispatcher. The term *talkgroup* is used to identify a virtual communications channel. It is possible to have more talkgroups than actual radio frequencies on a trunked radio system. The trunking control computer assigns a talkgroup to a particular frequency for communicating. When a talkgroup is not being used, it does not use system resources. In most cases, a dedicated data channel is used to communicate the channel assignments and special features between the controller and each radio on the trunked system. Originally most trunked systems used proprietary technology, but most recent systems, in particular those that are P25-based, use standards-based technology.

Trunked user radios are typically capable of having between 48 and 1,000+ talkgroups, depending on the radio brand and model. Trunked technology is generally expensive to implement and manage. Most trunked systems require regular system controller and software updates, typically unnecessary with conventional systems. Simulcast technology is often also deployed by many trunked system vendors. Trunked technology is used on many public safety systems throughout the world.

None of the Park County's primary radio systems is trunked. However, the Montana "state" radio system is a trunked system. Should the state of Montana system ever be expanded to provide adequate coverage in Park County, Park County could become a user of the state system.

[26] IP, or Internet Protocol, is a network and transport protocol used for exchanging packet data over a network, such as the Internet.

Advantages

- Spectrum-efficient when limited frequencies are available.
- Dispatchers and radio users do not need to worry about frequency selections.
- Advanced communications features commonly come standard with most trunking systems.

Disadvantages

- A dedicated communications link must connect the dispatch center with each repeater radio site.
- Costs more than constructing multiple standalone repeater systems.
- Requires higher levels of preventive maintenance and upgrades.

Because of the relatively small number of channels needed by users in Park County, the high initial and ongoing costs and complexity of a trunked system likely cannot be justified at this time.

Modulation Modes (Air Interface)

In addition to having multiple frequency band and system architecture options, there are several modulation mode (air interface) options available for LMR systems. The air interface is the radio-based link between the subscriber units and the base stations and/or repeaters. There are two primary categories of air interface: analog and digital. Analog radio technology has been in use for nearly 100 years and has fundamentally changed very little. On the other hand, digital radio technology has been used in earnest for less than 20 years and comes in many varieties, most of which are not compatible with one another. The following sections describe the most common LMR air interface technologies and their viability with regards to the Park County radio system upgrade project.

Analog FM

Even with significant moves toward digital technology around the country, analog FM is still the most commonly used LMR air interface. Park County's primary dispatch channels operate in analog mode, as do those of most surrounding mutual aid agencies. Widespread use of analog technology facilitates straightforward interoperability.

With the continued move toward digital systems, many manufacturers are dropping support for certain analog systems, particularly trunked analog systems. Conventional analog repeaters, base stations, and subscriber units are still widely available and are generally less expensive than comparable digital versions. A wide variety of analog mobile and portable radios are available at a variety of price-points, with all generally being compatible with one another.

One advantage of analog technology is that, unlike digital, it is compatible with tone/voice alerting systems; such systems are still used by fire and EMS agencies in Park County. In addition, even though analog voice signals can get "scratchy" in weak coverage areas or become difficult to understand when interference is present, oftentimes a transmission can still be understood, or at the very least the users know a transmission was attempted and a retry can be requested. This often is not the case with digital systems.

Limited encryption options are available for analog radio systems and are often not standards-based. Range and intelligibility are often impacted with analog encryption systems. P25 digital is a much better option for encrypted communications.

If minimizing costs is a primary factor and encryption and/or trunking is not needed, analog FM could be an appropriate technology for some or all radio channels in Park County.

Project 25 Digital

Project 25 is a suite of open standards for digital two-way radio communication typically used by public safety agencies in North America. Development of the standards started in the early 1990s and continues today. P25 is intended to ultimately provide a foundation for interoperability. However, its use is not mandated, and it should not be considered a "silver bullet" for interoperability. Users must not only have P25-capable equipment but their equipment must also operate on the same frequency band(s) as the agencies they intend to interoperate with. For example, a VHF P25 radio *cannot* communicate with an 800 MHz P25 radio, even though they are both P25-capable (unless, of course, multi-band radios are used). As P25 infrastructure is deployed in more areas, interoperability is expected to improve. However, it will still be many years, if ever, before P25 reaches all parts of the country, particularly in rural areas. This is primarily due to the significant expense of replacing analog infrastructure and subscriber equipment with P25 equipment.

There are two primary variants of P25: *Phase 1* and *Phase 2*. P25 Phase 1 uses a 12.5 kHz narrowband-compliant *frequency division multiple access* (FDMA) digital air interface, whereby each channel supports a single talk-path. P25 Phase 2 is a newer technology that uses a 6.25 kHz-equivalent narrowband-compliant two-slot *time division multiple access* (TDMA) digital air interface, which support two talk-paths in each 12.5 kHz channel.

At least a basic level of compatibility exists between all vendors' P25 equipment, allowing end users to have a choice when selecting equipment. However, many vendors also offer proprietary "features," which if relied upon can consequently reduce equipment choices. All P25 Phase 2 radios are capable of also operating in Phase 1 mode, providing backward compatibility if configured properly. Further, all P25 radios are capable of analog operation. With proper equipment programming, user training, and procedures, this can reduce issues interoperating with surrounding agencies that are still using analog systems.

Digital Audio

P25 systems employ digitally encoded audio using a process known as *vocoding* ("voice encoding"). Compared to a traditional analog system, digitally vocoded audio improves the spectral efficiency and thus the capacity of the system, while also enabling features such as background noise cancellation. One of the primary advantages of P25 is the ability to use standards-based encryption, with no loss in audio quality or range compared to unencrypted operation. By comparison, analog encryption techniques normally result in a reduction in audio quality and/or coverage.

Because of the way it reproduces audio, digital systems sound *different* than analog systems. Whether it is better or worse than analog is subjective, but suffice it to say that it may take some users a short period of time to get used to the difference. In addition, because there is no discernable background noise or "static" in a digital system, if a user keys his or her radio but does not speak, other users may not know the channel is actually in use because it will remain silent. In addition, there is no "squelch tail" with digital systems as there often is with analog repeaters.

Unlike analog systems, there generally is not a gradual degradation in service quality when approaching the edge of coverage with a digital P25 system. Similar to digital cellular telephones, coverage/audio quality is usually very good until hitting a sharp drop off to very poor service or even out of range. Digital systems such as P25 are often able to maintain high quality audio at greater distances from radio sites than comparable analog systems, which can result in users experiencing "better" overall coverage.

An important downside of P25 to consider, particularly in mountainous environments such as those found in southern Park County, is its susceptibility to *multipath* and other types of interference. Because reliable decoding of the digital signal is required to recover the transmitted audio, any corruption of the signal can result in garbled audio or no audio whatsoever. Multipath interference, often resulting from signals reflecting off of hills, canyon walls, or even multiple simulcast transmitters, can be highly destructive to P25 signals. Although analog signals are affected by such interference as well, it is often still possible to understand the message being transmitted through the distortion.

Other Considerations

P25 radios are more expensive than comparable analog-only radios. Many grants, however, require the purchase of P25-capable radios. While this may not be an issue for radios purchased under a grant, if additional radios are needed at some point in the future and grant funding is not available, it may cost significantly more to purchase the same model(s) of P25 radio than it would have for comparable analog-only radios.

Currently, in Park County only the trunked "state" system operates in P25 mode. This system is not generally used for day-to-day dispatch operations for Park County users, however.

If a trunked system or use of encryption is desired, P25 digital (either Phase 1 or Phase 2) would be the most appropriate technology for Park County.

DMR

Digital mobile radio (DMR) is an open digital radio standard specified for professional mobile radio users developed by the European Telecommunications Standards Institute (ETSI) and is used throughout the world. The standard was originally ratified in 2005. DMR was designed as a low-cost, entry level radio system for commercial use. It is typically targeted at the professional industrial and business markets and was not designed for mission-critical communications such as public safety. DMR is available for conventional operation ("Tier II") as well as for trunked operation ("Tier III").[27]

DMR uses a 6.25 kHz-equivalent narrowband compliant two-slot TDMA air interface (12.5 kHz per channel), ***but it is not compatible with P25***. DMR systems are intended to have low complexity, low cost, and offer competition between radio manufacturers, facilitated by the open standard. DMR also offers advanced capabilities such as location-based (GPS) tracking, text messaging, and allows for third-party development of other applications. As with P25, however, some manufacturers have added proprietary "features" that may be incompatible with other vendors' radios.

DMR systems typically do not offer the redundancy or other important features that are available with public safety-grade systems such as P25. For instance, the primary DMR suppliers do

[27] One of the most popular DMR products in the United States is Motorola's *MOTOTRBO™* product.

not offer simulcast capability. Also, the ETSI standard does not itself support encryption, although some vendors have implemented encryption using standard algorithms. DMR portable and mobile radios are not normally designed to have the same survivability (e.g., hardening, waterproof) and ergonomics as many public safety radios. Further, options such as noise canceling microphones are not typically available, which can be critical for life-safety operations in high-noise environments.

Because it was not designed for mission-critical public safety communications, **ADCOMM does not recommend Park County consider DMR for its radio system upgrade.**

Backhaul Options

An important consideration for an LMR system is the connectivity between remote radio sites and the dispatch center. Various backhaul technologies are available, each having its own distinct advantages and disadvantages, and are described in this section. Importantly, the type(s) of backhaul employed can have an impact on the overall reliability of the system. Depending on what makes most sense for the individual radio sites, it is possible that a combination of backhaul methods could be used for the upgraded Park County radio system.

Leased Lines

Leased lines, sometimes referred to simply as *copper*, *telco circuit*, *phone line*, or T1, are dedicated communication circuits typically provided by a landline telephone company used for connecting remote radio sites to a centralized location, often a dispatch center. Such circuits are available with different capacities. Leased lines are not always available at remote mountaintop sites, however.

The primary advantage of using leased lines is that they often have low up-front costs and can often be installed in a relatively short period of time. However, the ongoing costs, depending primarily on line distance and capacity, can be high. In addition, leased line reliability is not always adequate for mission-critical communication systems. The maintenance and repair of such lines is out of the control of the customer; the service provider must be relied upon to restore outages. In addition, leased lines are not always suitable for implementing simulcast technology.

Licensed Microwave

FCC-licensed private point-to-point microwave systems can provide highly reliable, high-bandwidth connections to remote radio sites. The most common microwave bands include 6 GHz, 11 GHz, and 18 GHz. Microwave systems require line-of-sight between path endpoints, which can pose significant challenges in some areas, particularly in southern Park County. In addition, microwave paths are distance-limited, with higher frequencies being limited to shorter paths. Further, higher frequency microwave paths, including those at 18 and 23 GHz, can be negatively impacted by rain and snow, causing outages or reduced performance.

The 960 MHz band can be used to provide a "microwave like" radio link system supporting up to six circuits or so. This equipment is less expensive than standard microwave and is often used in rural areas where a large number of circuits are not needed.

Licensed microwave has the advantage that it is controlled entirely by the licensee and is afforded interference protection from other microwave users. Reliance on a third party is not

necessary for repairs and maintenance. In addition, with proper system design, such as use of loop protection and/or *monitored hot-standby* (MHSB), license microwave can provide robust redundancy in the event of a partial system outage. The stability of microwave makes it a good choice to use with a simulcast system. Since microwave radios operate continuously, their use at alternative-power (e.g., solar) sites can be challenging due to their power supply requirements.

Upfront costs can be high for licensed microwave equipment. However, ongoing costs are minimal, and it may even be possible to generate revenue from spare capacity or trade for other services.

Unlicensed Microwave

Unlicensed microwave, while similar in many respects to *licensed* microwave, does not afford any interference protection from other users. As a result, its reliability is impossible to guarantee, especially since the interference environment can change over time. Many unlicensed microwave bands, including 2.4 GHz and 5.8 GHz, are shared with consumer devices such as wireless routers, cordless phones, and even Bluetooth devices.

Although unlicensed microwave equipment can be less expensive than licensed equipment and there is not any coordination or licensing costs, its use is not generally recommended for mission-critical communication systems.

Fiber

Fiber optic cables are able to provide high-capacity communications connectivity over both short and long distances. The chief impediment to using fiber is its installation, which can be cumbersome and expensive, particularly when installed underground. Where it is already in place, fiber can be a good option for connecting radio sites and dispatch centers. However, it may not be practical to install new fiber to remote mountaintop radio sites. The stability and bandwidth capacity of fiber make it suitable for simulcast operations.

Fiber connections are generally reliable; however, unlike microwave they are subject to "backhoe fades," where an underground cable is inadvertently cut by digging. Such cuts can take many hours (or longer) to repair. In addition, fiber cables and telephone lines installed above ground can be susceptible to natural and manmade disasters such as fires.

RF Links

Point-to-point RF links, using radios in non-microwave frequency bands such as VHF or UHF, can be used for connectivity to remote radio sites. Such links are relatively low capacity compared to microwave and fiber since a separate link is needed for each remote base station or repeater. Although RF links can potentially be operated over long distances, frequency availability can make this difficult in some areas. The additional equipment associated with an RF link also increases the number of failure points in the system.

In areas where phone lines and fiber are not available and microwave is impractical, RF links can be a low capacity yet effective, moderate-cost alternative.

RF Control Stations

The least desirable method of controlling remote repeaters is the use of RF *control stations*. These are essentially mobile radios configured to access the radio system as any other subscriber would by simply transmitting on a repeater's receive/input frequency and listening on the

repeater's transmit/output frequency (control stations cannot be used to access simplex base stations). Because they simply act as another subscriber radio, control stations do not offer *console priority* capability, whereby a dispatcher can override another user on the system, as may be necessary in the event of a stuck field user's microphone. Leased lines, microwave, fiber, and RF links generally do offer console priority.

Control stations are relatively inexpensive to implement, although in some cases it may be necessary to install them at a remote location that is able to access the necessary repeater(s). Depending on how they are implemented, control stations can increase system complexity and the number of failure points.

Other Technology Considerations

In addition to the primary system technology options detailed above, some additional options and technologies worth noting are included in this section.

Shared-Use Channels

In the case of a conventional system (as opposed to a trunked system), because of the limited availability of new frequencies, the deployment of *shared-use* channels would improve radio resource efficiency, in particular for tactical and/or on-demand needs. For example, today in southern Gallatin County, the primary dispatch channel is a shared-use channel, used by both fire/EMS and law enforcement. While perhaps not always ideal, shared-use channels can be beneficial in some instances since it facilitates straightforward interoperability between agencies that are all using a common radio channel.

Vehicular Repeaters

A *vehicular repeater* is a device installed in a vehicle and connected to a mobile radio that acts as a repeater for a relatively small area around the vehicle, allowing one or more nearby users to use portable radios to "talk through" to another radio channel. This allows use of portable radios in areas where only mobile coverage is available.

Vehicular repeaters can be operated in a *cross-band* configuration, whereby a portable radio on one frequency band (e.g., UHF) is used to talk through to a channel on another frequency band (e.g., VHF). This configuration simplifies the necessary in-vehicle equipment configuration. It is also sometimes possible to operate an *in-band* vehicular repeater, whereby the portable radio and mobile radio operate in the same band (e.g., both VHF). This configuration normally requires additional equipment, such as filters, to be installed in the vehicle. There may also be restrictions on which channels can be accessed due to frequency separation requirements of the repeater. If a cross-band configuration is used, portable radios would of course need to be capable of operating in the associated frequency band (e.g., UHF in the aforementioned example).

Regardless of the band configuration, caution should be taken with the use of vehicular repeaters. Interference and device conflicts can occur when more than one vehicular repeater is enabled in the same vicinity. Manufacturers have implemented algorithms to mitigate such problems; however, conflicts might still occur, so their use should be coordinated and users be made aware that conflicts can occur. The devices should be disabled or powered off when not in use.

In cases where portable coverage is needed but only mobile coverage is available, **ADCOMM believes limited use of vehicular repeaters, particularly in less populated areas, could be beneficial in Park County.**

Bluetooth Mobile Microphones

Bluetooth has been used for a decade or so to connect wireless accessories to cellular phones and more recently for public safety portable radio accessories. A more recent development has been the use of Bluetooth technology to allow a wireless microphone to be connected to the vehicle's mobile radio. The use of a Bluetooth microphone allows a law enforcement officer or other responder to use their mobile radio up to around 1,000 feet depending on terrain. Certainly, for most traffic stops and accident scenes, the range of a Bluetooth microphone is more than adequate.

The Bluetooth microphone is not a replacement for an officer's portable radio. However, it is an alternative to a vehicular repeater and is much simpler to operate. Multiple Bluetooth microphones can operate in the same area and the audio is digital encoded so the different microphones do not interfere with each other. **ADCOMM recommends Park County try Bluetooth microphones for the Sheriff's radios by testing on one or two vehicles.**

FirstNet

FirstNet is an independent authority within the National Telecommunications and Information Administration (NTIA) of the Federal Government, created under the Middle Class Tax Relief and Job Creation Act of 2012. The purpose of FirstNet is to establish, operate, and maintain a nationwide interoperable public safety broadband communications network. To fulfill these objectives, Congress allotted $7 billion and 20 MHz of radio spectrum in the 700 MHz band to build the network. It is widely recognized, however, that significant additional funding, with varying estimates between $10 billion and $50+ billion, will be needed to fully construct the network.

The FirstNet network is intended to be a standards-based *Long-Term Evolution* (LTE) network—the same technology employed in many commercial "4G" cellular networks. Initially, the LTE network will provide wireless data service only; there will be no standards-based voice or PTT capability. The vision, however, is to eventually be able to support PTT and other voice traffic, using technology such as *Voice over LTE* (VoLTE). FirstNet is essentially a public safety cellular system that would provide similar coverage as commercial cellular systems provide.

Except for some very small initial build-outs around the country, the FirstNet system does not exist today. If successful, it will take many years and significant additional funding to fully construct the network. Due to efficiencies of scale and usage demand, it is anticipated that the network will first be constructed in larger cities, followed by smaller cities and eventually rural areas.

While FirstNet deployment is being started for data services and may provide some ability to provide data connectivity in portions of Park County, the standards for the implementation of standardized mission critical push-to-talk services are still 2 to 3 years away. In addition, while FirstNet may provide some coverage along major highways, it will not provide coverage in rural and remote areas. Interoperability with VHF users will also be an issue. As a result, ADCOMM does not recommend the use of FirstNet for voice services for Park County.

Satellite Services

Voice Service

For remote areas without radio coverage, an alternative for voice communications may be satellite service. Satellite vendors have been developing new PTT options for use in remote areas. There are several operational issues with these units, especially in routine public safety service, latency being one of the biggest, presenting an alternative to explore in more detail.

The satellite voice industry has evolved toward a cellular business model with multiple providers offering portable handsets with access fees and rate plans. Handsets can be purchased from $500 to $1,750 with monthly access and rate plans costing between $50 and $100 per month. Annual rate plans targeting disaster use of the phone with bursts of usage are also available from most providers. The phone kits include a magnetic mount antenna for installation on a vehicle.

Regular use of the satellite handsets has operational benefits over contingent use of the handsets. All too often the satellite handsets are acquired as a part of a disaster plan and forgotten in a closet in the emergency operations center. When needed, these handsets often suffer from battery issues, service disconnects due to lack of usage, users unfamiliar with the devices, and a host of other operational issues. By regularly exercising the handsets, users are familiar with their use and service issues are more quickly rectified.

Several services were researched and Table 12 summarizes their main features and limitations.

TABLE 12
Satellite Voice Service's Main Features and Limitations Summary

	Iridium PTT	Iridium Voice	InmarSat Isat	Globalstar Phone	Explorer MSAT G3
Device MSRP	$750-$1,500	$750-$1,500	$700-$1,000	$499	$4,795
Communication Channel	PTT One to many	Phone call One to one	Phone call One to one	Phone call One to one	PTT One to many
Constellation Type	LEOSAT	LEOSAT	GEOSAT	GEOSAT	GEOSAT
GPS Tracking	Yes	Yes	No	Yes	N/A
Battery Life	5 Hours	4 Hours	8 hours	4 Hours	Mobile Installation
Cradle Docking Station	Yes	Yes	Yes	Yes	
Speaker-Microphone	Yes	No	No	No	
Bluetooth	No	Cradle Enabled	Yes	No	Yes
Channel Patching via Port / Interface-Port	Yes	No	No	No	Yes
Dimensions (inches)	5.5 x 2.4 x 1.3	5.5 x 2.4 x 1.3	6.7 x 3 x 1.4	5.3 x 2.2 x 1.5	9.8 x 5.9 x 2.4 Terminal Only
Weight	9.3 oz	9.3 oz	11.2 oz	7.1 oz	4 lbs

Of the services listed, two types of satellite constellations are used: LEOSAT (low earth orbiting satellite) and GEOSAT (geostationary earth orbiting satellite).

LEOSAT-based services utilize satellites that constantly orbit the earth. As such, in the event that call cannot be made due to an obstruction, the end user simply has to wait until there is a

satellite pass in an unobstructed portion of the sky. For example, when calls are made from valleys or behind hills coverage may not be constant, but it will also never be fully lost. LEOSAT-based service would work well for "boots on the ground" communications for high-mobility situations.

GEOSAT-based services utilize satellites that are in a fixed location above the earth. As such, there must be a clear line of site to a satellite; southern-oriented obstacles such as tree and hills will block the signal. While service would be available throughout Park County, it would be limited by locally surrounding terrain as it needs clear visibility towards the southern horizon. GEOSAT-based service would work well in limited areas and for stationary team leader communications, assuming that the team leader can be positioned in a location with southern horizon visibility.

Additionally, of the services listed, two types of voice channels are used: phone and PTT.

Phone service provides voice communications with a 10-digit phone number. This type of service provides one-to-one dialed communications and is typically conversational in information exchange, similar to a phone call.

PTT service provides voice communications similar to the County's two-way radio system. This type of service provides one-to-many communications and is typically for tactical information exchange, similar to two-way radio. PTT service also allows for interface options that are used in two-way radio, such as channel patching through accessory jack, direct dispatch console connection, and Bluetooth speaker-microphone options. There will be some latency when setting up the first PTT call to make sure all of the users in the group are connected with follow-on transmissions being quicker. Users may find the latency in normal operation troublesome. However, in areas where there is no radio coverage, it may be the only viable option.

ADCOMM believes satellite phone PTT operation may be a viable alternative in the extreme remote areas of the county until the radio system can be expanded to cover those areas.

Satellite: Data Service

For remote areas without radio coverage, satellite data service provides a local Internet access point. This allows for voice, texting, and data communications through paired Android and iOS devices and Wi-Fi based apps. Texting allows for a more economically feasible county-wide communications when compared to satellite phones. Data connectivity may be a necessity for an ongoing large response. Similar to satellite voice services, continuous line-of-sight satellite visibility is required for reliable connectivity.

Much like the satellite voice industry, the satellite data industry has multiple providers, access fees, and rate plans. Data terminals can be purchased from $750 to $1,250 with monthly access and rate plans costing between $50 and $150 per month, with data speeds ranging from 2.4 kbps to 240 kpbs. Data terminal options include hand-held portable devices and transportable devices with fully integrated antennas and batteries, as well as deployable kits that require an external power source and antenna set-up. Generally speaking, a smaller data terminal correlates to a slower throughput.

Four services were researched and Table 13 summarizes their feature sets and limitations. The services are listed in cost order, least to greatest.

Of the four services listed, two types of satellite constellations are used: LEOSAT and GEOSAT.

LEOSAT-based services utilize satellites that constantly orbit the earth. As such, the antenna does not have to be pointed and partial coverage may be possible in deep canyons or valleys when the satellite is directly overhead; coverage may not be constant, but it will also never be fully lost. While this allows for ease of use for the end user and more county-wide coverage and mobile connectivity, the tradeoff is slower data speeds; Iridium GO has a maximum throughput of 2.4 kbps. High mobility access would be ideal for tactical communications and forward operations.

GEOSAT-based services utilize satellites that are in a fixed location above the earth. As such, the antenna must be pointed and a clear line of site; obstacles such as trees and buildings will block the signal. While this introduced some complexity, requires end user technical expertise, and requires stationary use, higher data throughput is possible; InmarSat IsatHub has a maximum downlink throughput of 384 kbps. Stationary access with high throughput would be ideal for a large-scale staging effort or field-EOC.

Summary

Although there are a variety of LMR technology options available, ADCOMM believes there are two primary options worth considering for Park County.

Given the relatively small number of channels needed in Gallatin County, it is believed that the expense and complexity of a trunked system is not warranted. As such, a multi-channel, conventional simulcast system is believed to be most appropriate as the foundation for Park County's updated radio system, perhaps augmented with some combination of standalone repeaters, transmitter steering, and/or multicast to cover outlying areas. A move to simulcast would provide significantly improved coverage for users as well as simplified operation for both field users and dispatchers alike. ADCOMM assumes deployment of an expansion of Park County's radio systems will occur over several budget cycles. As a result, ADCOMM proposes a phased approach to implementing Park County radio system improvements.

The primary option would be to continue to use VHF for the new system, which would allow many of the existing subscriber radios to be reused, at least for analog operation. If P25 is used instead, at least some subscriber radios would need to be upgraded or replaced. In addition, the limited availability of additional VHF frequencies may impact the number of channels that could actually be deployed.

TABLE 13
Satellite Services' Main Features and Limitations Summary

Features	Garmin inReach	Iridium GO	Globalstar Sat-Fi	InmarSat IsatHub	Explorer MSAT G3
Device MSRP	$399.99	$999.00	$999.99	$1,199.00	$4,795
Communication Medium	SMS Only	SMS / Data / Voice	SMS / Data / Voice	SMS / Data / Voice	Data / Voice
Constellation Type	LEOSAT	LEOSAT	GEOSAT	GEOSAT	GEOSAT + Cellular Seamless Roaming
Data Interface	Paired Device Virtual Keyboard Pre-Defined SMSs	Wi-Fi Paired Device	Wi-Fi Paired Device	Wi-Fi	Wi-Fi Paired Device RJ-45 Ethernet jack
Voice Interface	None	Paired Device	Paired Device	VoIP over Wi-Fi	PTT Speaker-Microphone
Simultaneous Users	1	5	8	5	N/A
Maximum Data Speed (UL/DL)	SMS Only	2.4 kbps / 2.4 kbps	9.6 kbps / 9.6 kbps	240 kbps / 384 kpbs	10 kbs / 1 Mbps
Portability	Handheld Device - Internal Battery - Integrated Antenna	Portable Device - Internal Battery - Integrated Antenna	Poor - External Power - External Antenna	Transportable: - Internal Battery - Integrated Antenna	Poor - External Power - External Antenna
Operational Scenarios	Pedestrian Use	Pedestrian Use	Long-Term Fixed Use	Long-Term Fixed Use Immediate Staging	Long-Term Fixed Use Immediate Staging Mobile
GPS Tracking	Yes	Yes	No	No	N/A
Battery Life	100 Hours	5.5 Hours	N/A Requires External Power	2.5 Hours (basic battery option)	N/A Requires External Power
Dimensions (inches)	6.5 x 2.7 x 1.5	4.5 x 3.3 x 1.3	12 x 11 x 4 Terminal Only	7.0 x 6.7 x 1.2	9.8 x 5.9 x 2.4
Weight	7.5 oz	10.4 oz	4.6 lbs Terminal Only	2 lbs	4 lbs

Final System Recommendations

Existing System Upgrade Recommendations — Site Specific

Based on the assessment of the existing radio system, ADCOMM recommends the following for Park County.

Dispatch Center

1. Implement VHF control stations that is able to communicate directly with the Meyers Flats repeaters.
2. Improve cable management.
3. Develop detailed line drawings and interconnections.
4. Improve site and equipment grounding.

Meyers Flats

1. Replace the existing transmitter combiner and receiver multicoupler to cable entry cables with 1/2-inch Superflex Foam Coaxial Cable (FSJ4-50B) and the appropriate Type-N Male connectors (F4PNMV2-HC) that have threaded clamping nuts that will not come apart when properly tightened.
2. Replace transmit antenna transmission line jumper cable and use proper cable hangers.
3. Resolve the receiver desense on Law Dispatch and Park County SO repeaters; additional filtering may be required or additional vertical separation between transmit and receive antennas may be required.
4. Remove and repurpose the unused equipment, specifically the Harris Mastr III base station and the VHF multicoupler/combiner equipment.
5. Schedule yearly vegetation growth removal.

North Hill

1. Replace the backup batteries to the repeater. The backup batteries should not be shared with other occupants.
2. Install AC power line lighting protection.
3. Install a generator for backup power.
4. Install backup batteries for the Law base station/control station.
5. Reprogram and align both the Fire and Law base stations/control stations for proper telephone line circuit levels (TX & RX 1.5 kHz FM deviation = - 10dB at 1 kHz test tone wireline levels).
6. Reprogram and test both the Fire and Law base stations/control stations for proper narrowband operation per FCC rules and regulations.
7. Install air conditioning.
8. Install bollards to protect guyed tower anchors.

9. Repair inoperative interior lighting.
10. Remove unused cabinets and equipment.
11. Implement rodent deterrent as the repeater is in an unclean environment that has considerable rodent droppings on the floor.
12. Install proper tower and shelter grounding at the site, including an expanded master ground bar on the inside of the shelter.
13. Audit existing antennas and remove all unused antennas and feed line systems.
14. Ascertain if Livingston Park County 9-1-1's antennas can increase its vertical isolation from the existing continuously keyed NOAA transmitter.
15. Improve receiver performance by repurposing the Meyers Flats unused receiver multicoupler to this site with a shared tower top receive antenna and additional filtering.

Wilsall Mountain (North Repeater)

1. Replace the PolyPhaser that is installed outside of the shelter. These devices are not designed for this environment. When replaced, the PolyPhaser should be installed inside the shelter.
2. Install a generator for backup power.
3. Install air conditioning.
4. Install AC power line lighting protection.
5. Improve the security of the site with a proper door lock and latch protector.
6. Implement rodent deterrent as the repeater is in an unclean environment that has considerable rodent droppings and nesting materials on the equipment shelf and the floor.
7. Update FCC license WQJC300 Location 3 to reflect the correct repeater frequency 154.415 MHz (FB2) and the mobile frequency 158.835 MHz (MO).
8. Improve site and equipment grounding.
9. Schedule yearly vegetation growth removal.

All Sites

1. Implement a yearly battery preventive maintenance schedule.

Voice Radio System Recommendations

Based on the technology options identified, in conjunction with the identified needs of the users, ADCOMM recommends the following for Park County:

All Channels

1. Continue operation of all systems in *conventional* (non-trunked) mode, appropriate for the relatively small number of channels needed.
2. Remain on VHF for radio system expansion.

Law

1. Utilize wireless speaker-microphones to improve portable coverage for routine stops in areas with good mobile coverage. Ranges up to 1,000 feet are possible.
2. Utilize vehicular repeaters for units operating in rural/remote areas.
3. **Phase 1:** Implement a two-site voted multicast system utilizing North Hill and Meyers Flats.
4. **Phase 2:** Improve central and south county coverage by expanding the multicast system with the following sites: Sheep Mountain, North Dome, and Cooke City.
5. **Phase 3:** Improve north county coverage by expanding the multicast system with the following sites: Kavanaugh and Brackett Creek. Improve Wilsall and surrounding areas by relocating the existing Wilsall Mountain (North Repeater) repeater to the Mercury Tower. Improve south county coverage by adding Elk Plaza to the multicast system.
6. **Phase 4:** Convert the county-wide multicast system to a county-wide simulcast system.

Figure 28 shows the first three phases of the law enforcement system improvement process. Note that each phase expands coverage out into the county and remote areas.

	LAW
Improvement Strategy	Voted Multicast
Phase 1 Sites	North Hill Meyers Flats
Phase 2 Sites	Sheep Mountain - New Site North Dome - New Site Cooke City - New Site
Phase 3 Sites	Kavanaugh - New Site - South of County Border Bracket Creek - New Site - West of Clyde Park Wilsall Mountain - Relocated to Mercury Tower Elk Plaza - New Site - Located in YNP
Phase 4 Long Term	Voted Simulcast

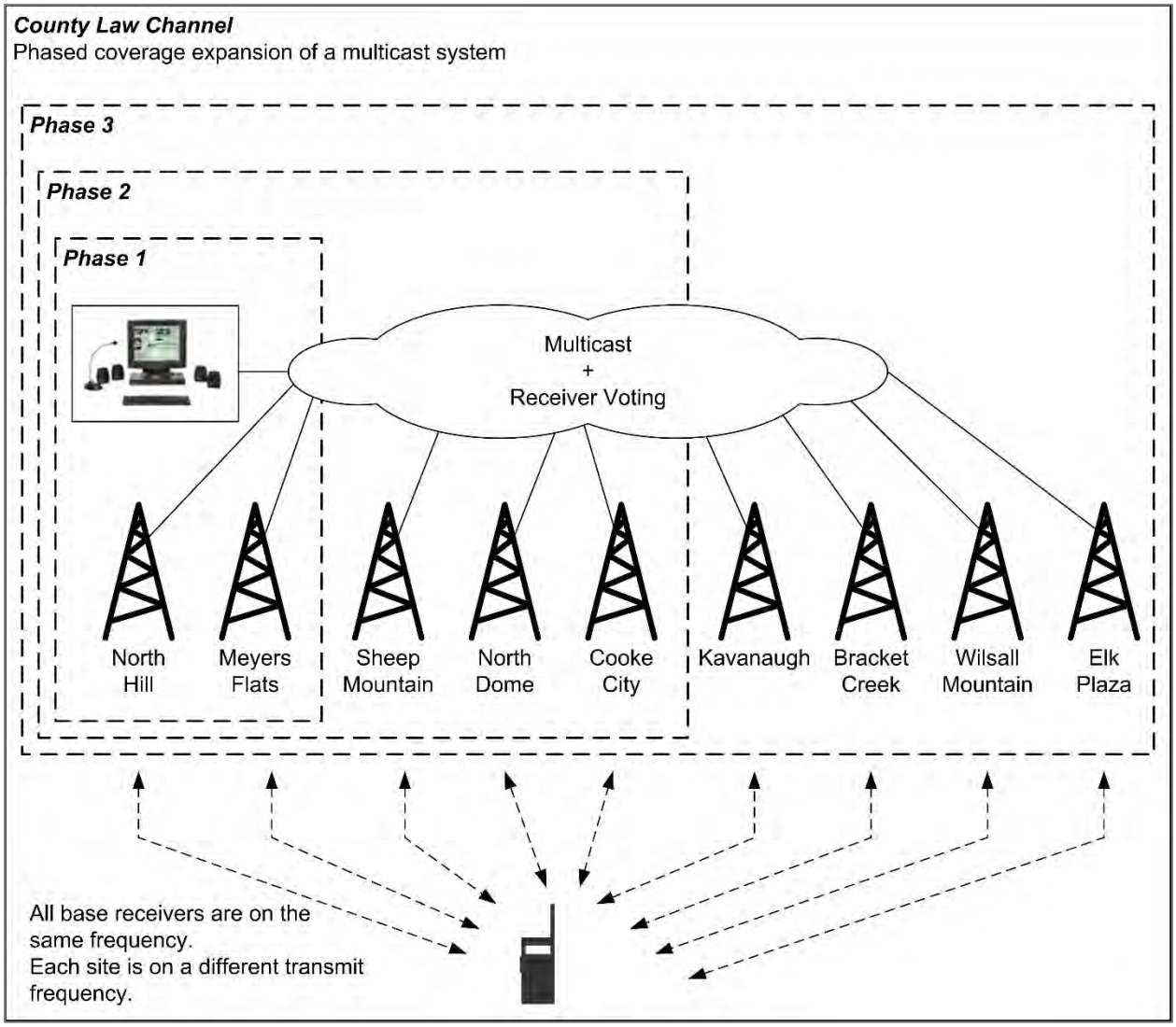


FIGURE 28
Law Enforcement System Improvement Process

The fourth phase is shown in Figure 29 with the same site but utilizes simulcast technology to make both the user and dispatcher operation easier. Note there is no other reason, other than cost, to not implement Phase 4 initially.

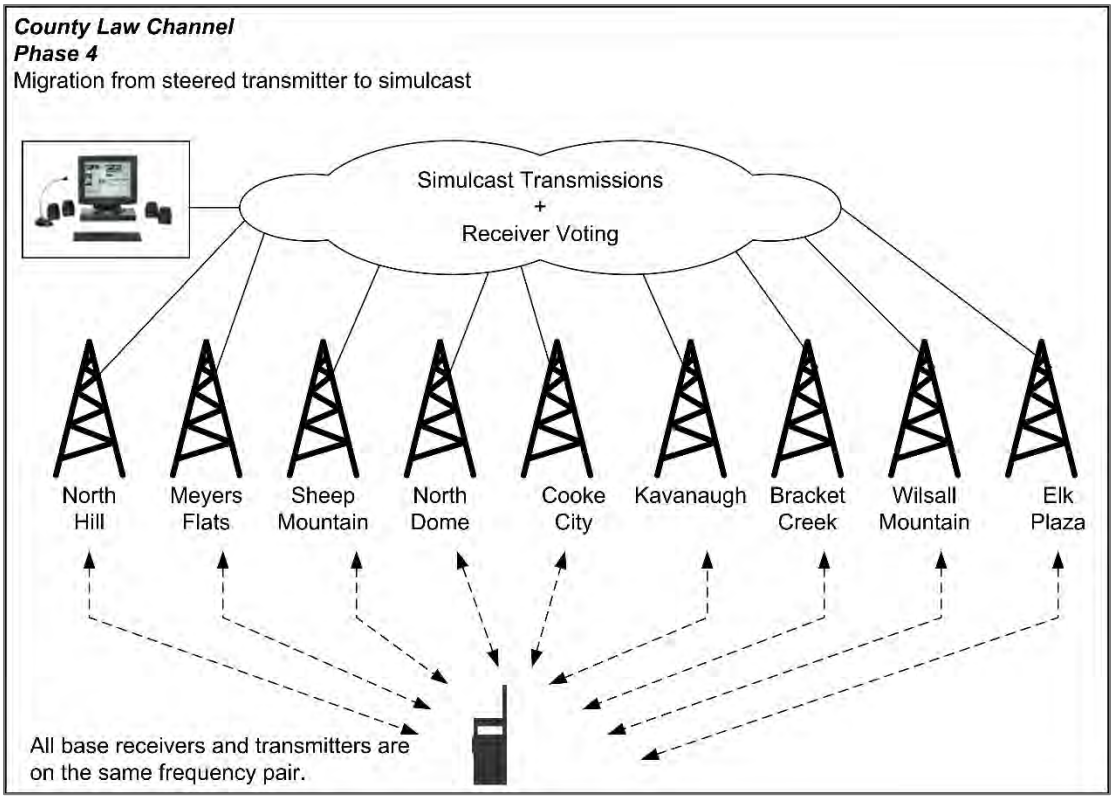


FIGURE 29
County Law Channel — Phase 4

Fire

1. Utilize wireless speaker-microphones to improve portable coverage for responses and aid calls in areas with good mobile coverage. Ranges up to 1,000 feet are possible.
2. Separate fire dispatch into two separate dispatch channels: County and Livingston. Livingston Dispatch would serve Livingston Fire and PC-RFD#1. County would serve the remaining outlying fire stations.

	FIRE	
Improvement Strategy	Transmitter Steering	
Dual Channel Strategy Fire Only	Improve County Fire Coverage	New Shared Channel for: - Livingston Fire - PC-RFD#1
Phase 1 Sites	North Hill Meyers Flats Wilsall Mountain	North Hill Meyers Flats
Phase 2 Sites	Sheep Mountain - New Site North Dome - New Site	Continue as-is
Phase 3 Sites	Kavanaugh - New Site - South of County Border Bracket Creek - New Site - West of Clyde Park Wilsall Mountain - Relocated to Mercury Tower	Continue as-is
Phase 4 Long Term	Voted Simulcast	Voted Simulcast

Livingston Fire

1. **Phase 1:** Implement a two-site steered transmitter system utilizing North Hill and Meyers Flats.
2. **Phase 2:** No change.
3. **Phase 3:** No change.
4. **Phase 4:** Convert the steered transmitter system to a simulcast system.

Figure 30 below is a diagram of the first three phases of the Livingston Fire recommendation. The main goal with this approach is to provide an immediate low-cost method to improve fire communications in the Livingston area.

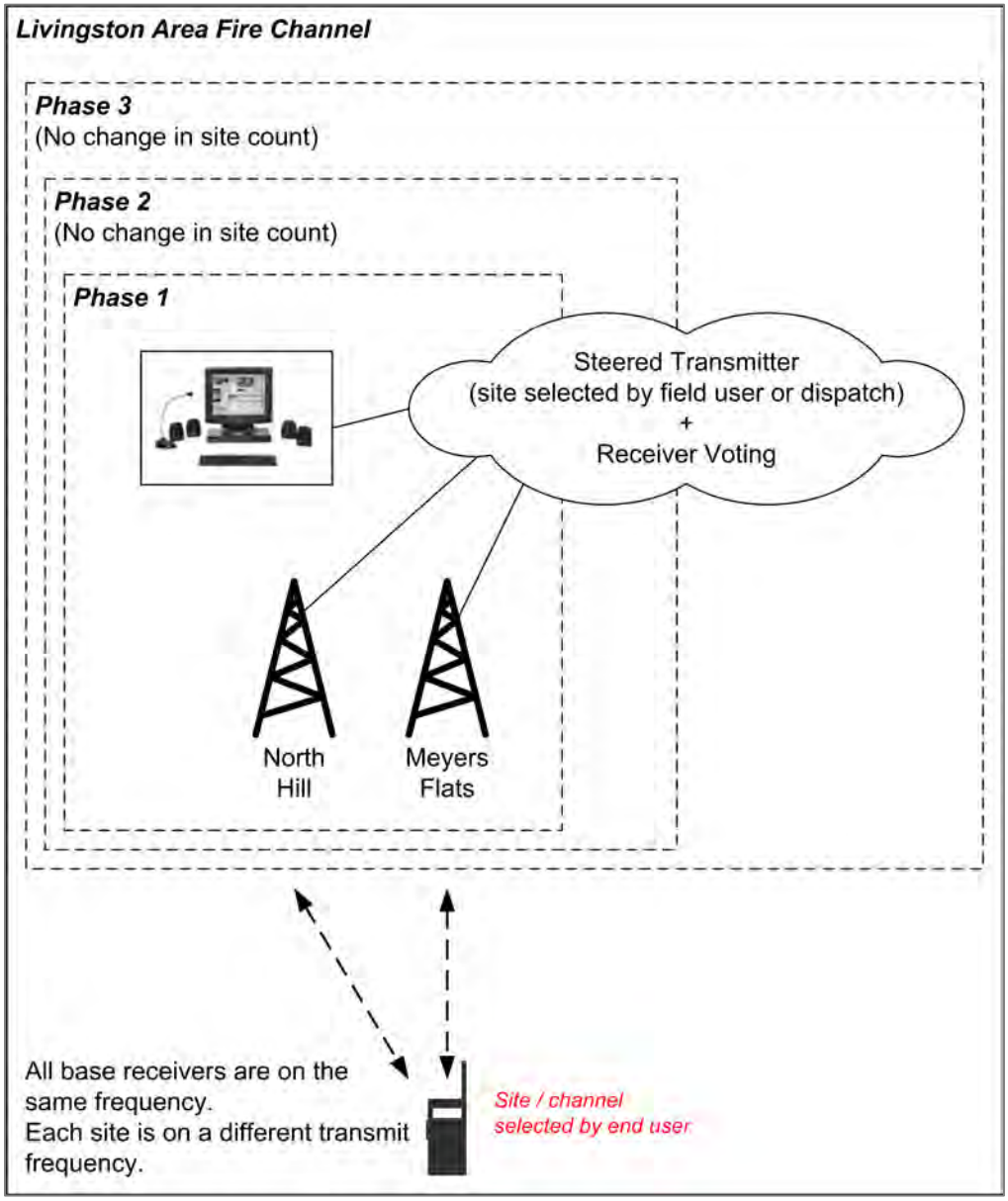


FIGURE 30
Livingston Area Fire Channel

Figure 31 for Phase 4 is for a simulcast system to provide coverage in the Livingston area so the dispatchers do not have to select sites based on user location. This will improve not only coverage but also improve dispatch operations.

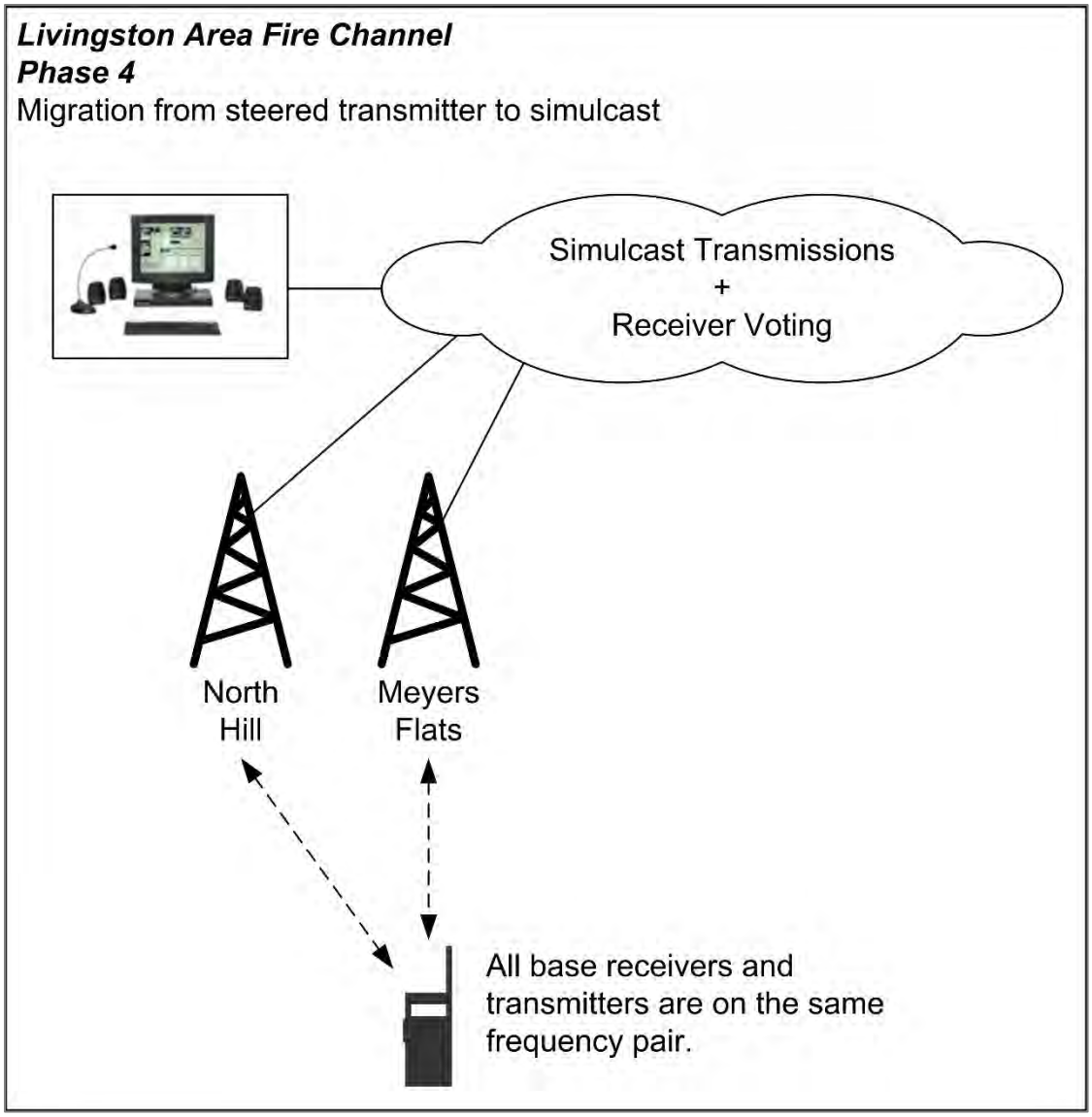


FIGURE 31
Livingston Area Fire Channel — Phase 4

County Fire

1. **Phase 1:** Implement a three-site steered transmitter system utilizing North Hill and Meyers Flats and Wilsall Mountain (North Repeater).
2. **Phase 2:** Improve central and south county coverage by expanding the steered transmitter system with Sheep Mountain and North Dome.
3. **Phase 3:** Improve north county coverage by expanding the steered transmitter system with the following sites: Kavanaugh and Brackett Creek. Improve Wilsall and surrounding areas by relocating the existing Wilsall Mountain (North Repeater) repeater to the Mercury Tower.

4. **Phase 4:** Convert the steered transmitter system to a simulcast system.
5. Continue to use the TAC-channels for fire ground.

Figure 32 shows the first three phases of the County Fire system improvements. Each phase increases the system coverage providing improved service to the rural and remote areas.

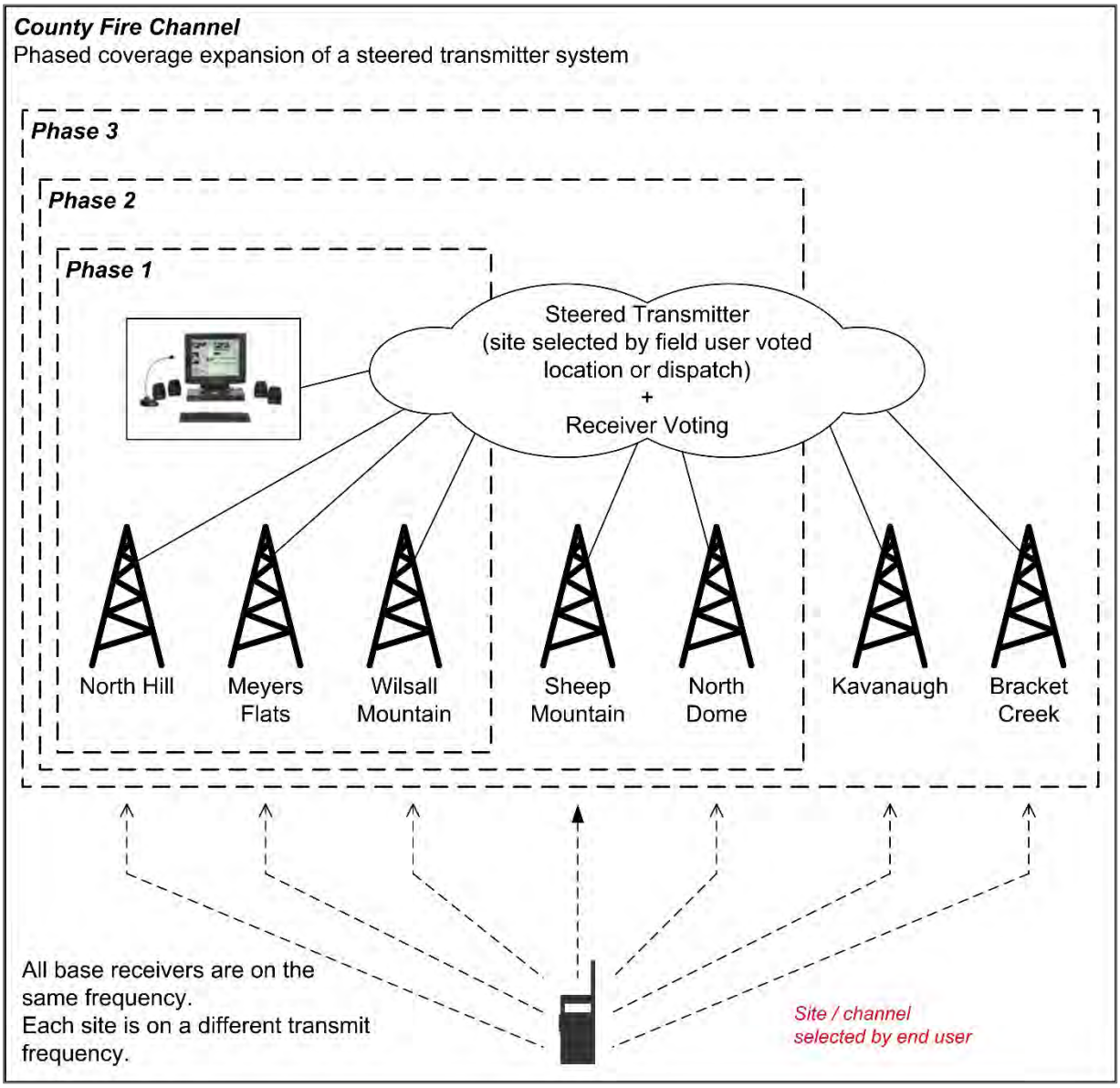


FIGURE 32
County Fire Channel

Figure 33 shows the final configuration in Phase 4. Note in this configuration the sites remain the same as in Phase 3 but they are converted to simulcast operation, which will reduce the complexity of the system for the users.

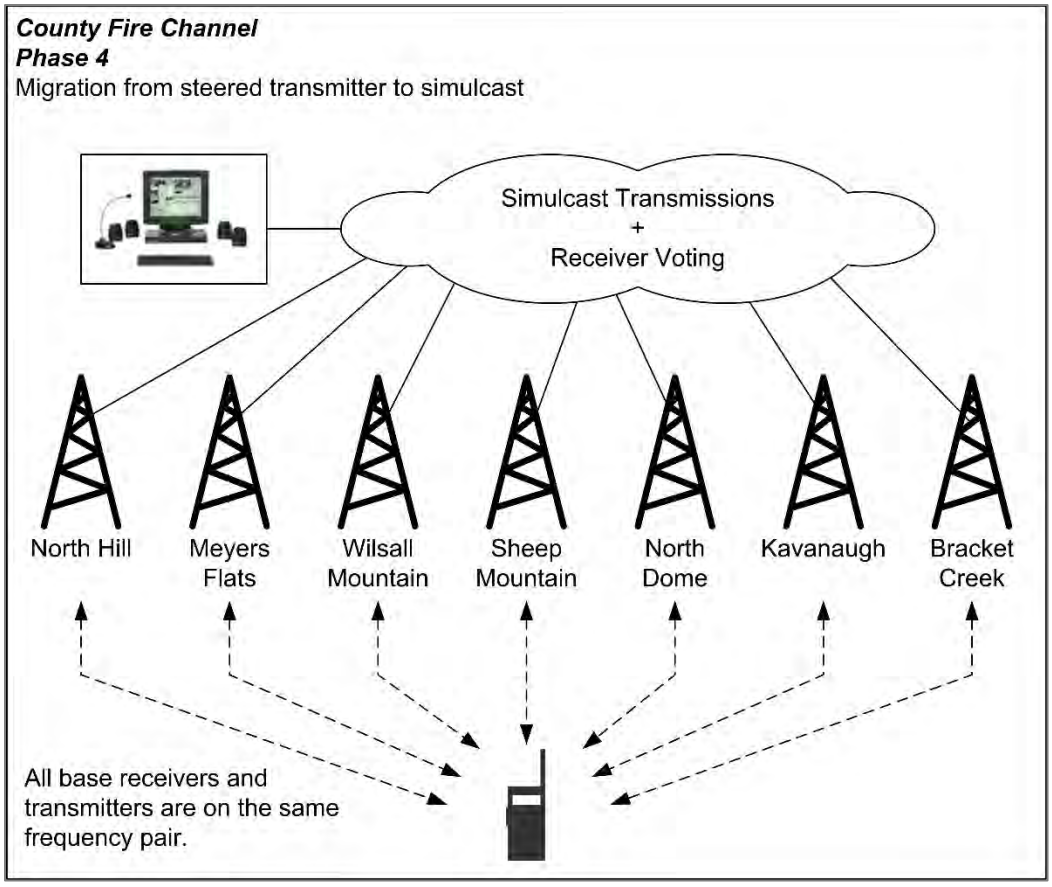


FIGURE 33
County Fire Channel — Phase 4

SAR

1. **Phase 1:** Continue to utilize existing portable repeaters for on-scene communications and consider procuring additional portable repeaters as necessary. Utilize portable satellite phone or PTT service for coverage in remote areas of the county.
2. **Phase 2:** Utilize satellite data service at staging areas for major responses.
3. **Phase 3:** Connect portable repeaters to dispatch via satellite voice service.
4. **Phase 4:** Connect portable repeaters to Law repeaters via UHF links.

Improvement Strategy	*SAR / Wilderness Coverage* Satellite and Infrastructure Utilization
Phase 1	Continue with portable repeaters - Expand repeater assets as necessary Portable satellite-phones for voice traffic Iridium service for text messaging
Phase 2	Satellite Gateway - Data at staging areas for major responses - Satellite Data Service Options - Iridium GO - 2.4 kbps - Globalstar Sat-Fi - 9.6 kbps - InmarSat IsatHub - 240/384 kpbs (UL/DL)
Phase 3	Portable repeaters with Satellite Gateway link - Deployed at staging areas for major responses - Satellite Voice Options – Channel Patch - Iridium PTT - Satellite Voice Options – Phone Patch - Iridium Phone - InmarSat Isat - Satellite Data Service Options - VoIP - Globalstar Sat-Fi - InmarSat IsatHub
Phase 4 *Long Term*	Portable repeaters with UHF links to LE sites

Law and SAR

1. Utilize satellite voice service for responses in remote areas.
2. Utilize satellite data service for long-term or major responses in remote areas.

See *Channel Plan and Coverage Expansion Recommendations* section below for map and table of recommendations.

Project Phasing Discussion

ADCOMM is proposing phasing the system improvement implementation primarily to support the ability to fund the improvements over multiple years. However, the implementation time should be limited to 4 to 5 years, if possible. Equipment models and types of equipment will change over periods much longer increasing the risk a system implementation started with one type or model of equipment may not be able to be completed with the same equipment resulting in design changes or having to change out some of the equipment purchased initially.

Proposed Sites Recommendations

To leverage existing assets and favorable site agreements, ADCOMM recommends deploying the proposed radio systems using existing Park County radio sites to the extent possible.

However, expanding radio coverage will require the addition of new sites. Recommended sites were selected based performing cursory site surveys in areas that required improved coverage. As part of the survey, the following was assessed:

- Location of site with respect to area of desired coverage improvement.
- Ability to implement a *green field* site, in locations where sites were not existent.
- Availability to implement point-to-point connectivity between sites.

Table 14 lists the recommended sites for the proposed radio system. See Figure 34 for site locations.

TABLE 14
Locations of Recommended Sites (Locations Listed from North to South)

Location ID	Coverage Target Within County	Location Type	Latitude	Longitude	Elevation
Kavanaugh	Northern Border	Existing Site	46° 07' 21.7" N	110° 39' 51.8" W	5925 feet
Wilsall Mountain	North County	Existing County	45° 59' 34.5" N	110° 40' 25.5" W	5305 feet
Brackett Creek Overlook	Clyde Park and Surrounding Area	Developed Area*	45° 52' 40.2" N	110° 39' 24.0" W	5475 feet
Sheep Mountain	County East Central	Existing Site	45° 45' 56.5" N	110° 20' 46.8" W	6260 feet
North Hill	Livingston Area	Existing County	45° 40' 25.6" N	110° 34' 02.5" W	4920 feet
Meyers Flat	Central County	Existing County	45° 35' 50.0" N	110° 32' 42.9" W	6500 feet
North Dome	County Southwest	Existing Site	45° 12' 28.2" N	110° 51' 22.6" W	8010 feet
Cook City Fire Station	Cook City and Silver Gate	Existing Site	45° 01' 9.4" N	109° 56' 11.4" W	7795 feet
Elk Plaza	Gardiner and Surrounding Area	Existing Site	44° 59' 11.7" N	110° 42' 57.0" W	6835 feet

**Developed Area* refers to locations where residential development is within several hundred feet. The assumption is that commercial power is available without extraordinary installation efforts.

FIGURE 34
Locations of Existing Sites and Proposed New Sites

Blue boxes represent existing sites within Park County's radio system.
Red boxes represent proposed new sites.

In addition to the remote radio sites and equipment, transmit control and voting equipment will be needed for the multicast and steered transmitter systems. Depending on the particular vendor chosen, it is anticipated that this equipment will generally consist of several racks of equipment. It is recommended that this equipment be installed at a readily accessible location, such as the 9-1-1 center, for maintenance purposes.

Recommended New Repeater Sites

ADCOMM identified new radio sites and developed coverage maps using already established and "candidate" radio sites in order to improve public safety radio coverage in the desired poor radio coverage areas identified by the 9-1-1 dispatchers and first responders.

ADCOMM used various candidate radio site combinations to develop a proposed radio system improvement design in order to provide the desired coverage throughout Park County.

The following high-level county view coverage prediction maps (Figures 35 to 41) are provided on a 1:250,000 map scale. Smaller scale coverage maps are provided in Appendix A.

- **Kavanaugh**: This existing microwave relay site is required for primary radio coverage into the northern portion of Park County and provides U.S. 89 transportation route coverage from approximately Wilsall to the Meagher County line, the area west of U.S. 89 to the Gallatin County line and the area east of U.S. 89 into the western facing slopes of the Gallatin National Forest. This site is recommended as a transmitter and voted receiver site for public safety communications. The coordinates of the site are 46° 07′ 21.7″ N, 110° 39′ 51.8″ W (NAD83) at an elevation of approximately 5,911 feet AMSL (Appendix C, Photograph K-1).

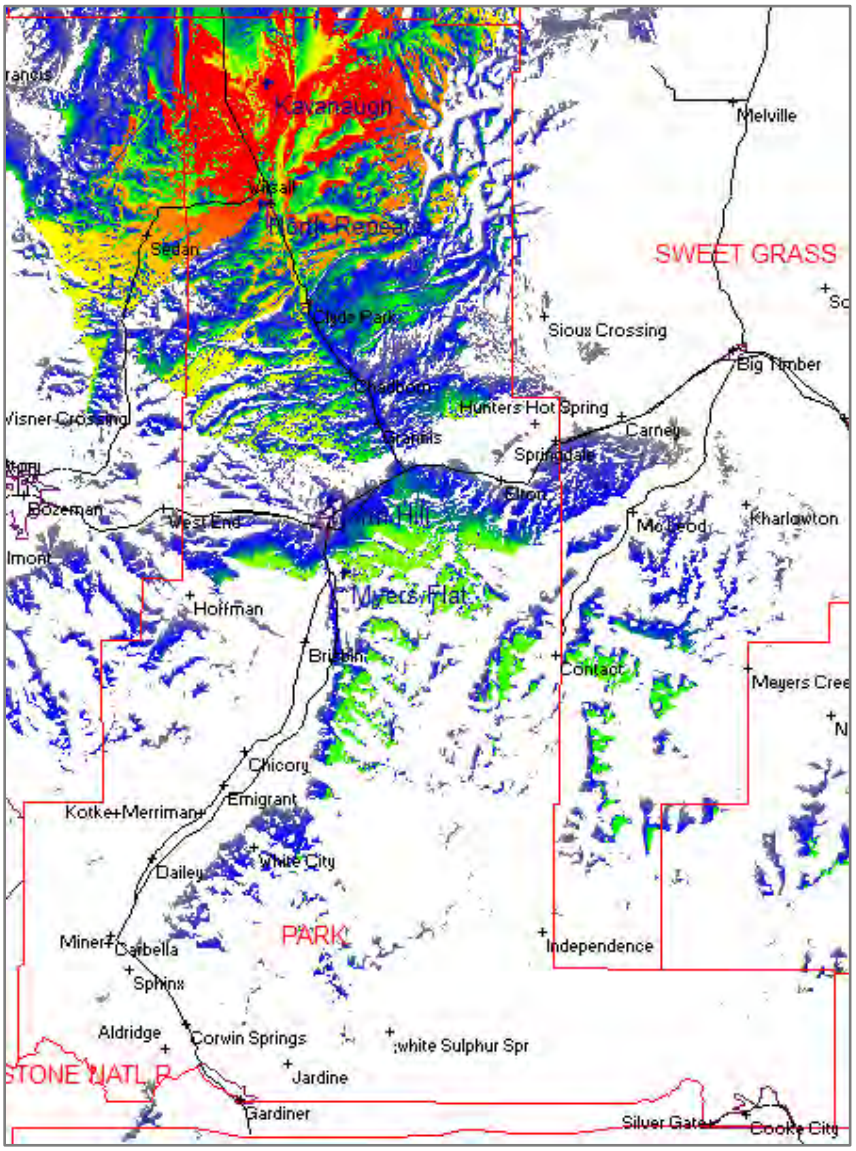


FIGURE 35
Kavanaugh Talk-Out Coverage Prediction

- **Brackett Creek Overlook**: This proposed radio site is required for primary radio coverage along U.S. 89 from approximately halfway between Wilsall and Clyde Park to approximately the Willow Creek crossing at U.S. 89, from approximately the headwaters of the Middle Fork Willow Creek near the Gallatin County line going east following the terrain north of Tobin Creek to the western facing slopes of the Gallatin National Forest. This site is recommended as a transmitter and voted receiver site for public safety communications. The coordinates of the site are nearby the structure at 45° 52′ 40.2″ N, 110° 39′ 24.0″ W (NAD83) at an elevation of approximately 5,470 feet AMSL (Appendix C, Photograph BC-1).

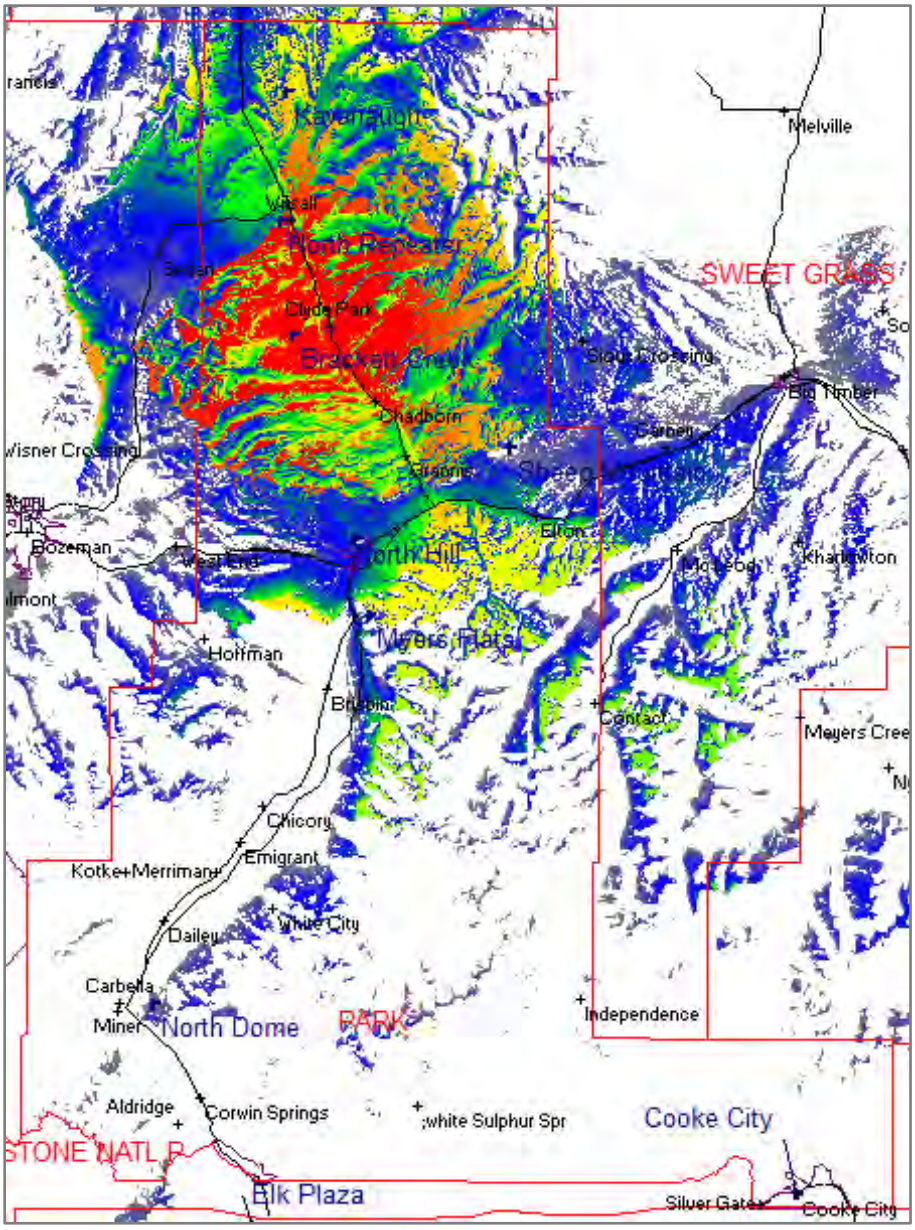


FIGURE 36
Brackett Creek Overlook Talk-Out Coverage Prediction

- **Sheep Mountain**: This proposed radio site is required for primary radio coverage along I-90 from approximately exit 337 east to Springdale at the Sweet Grass County line, the Hole-In-The-Rock Creek drainage north of Sheep Mountain, areas west of the Sweet Grass County line and the northern foothills of Mount Greeley from Mission Creek Road east to the Sweet Grass County line. This site is recommended as a transmitter and voted receiver site for public safety communications. The coordinates of the site are 45° 45′ 56.5″ N, 110° 20′ 46.8″ W (NAD83) at an elevation of approximately 5,470 feet AMSL (Appendix C, Photograph SM-1).

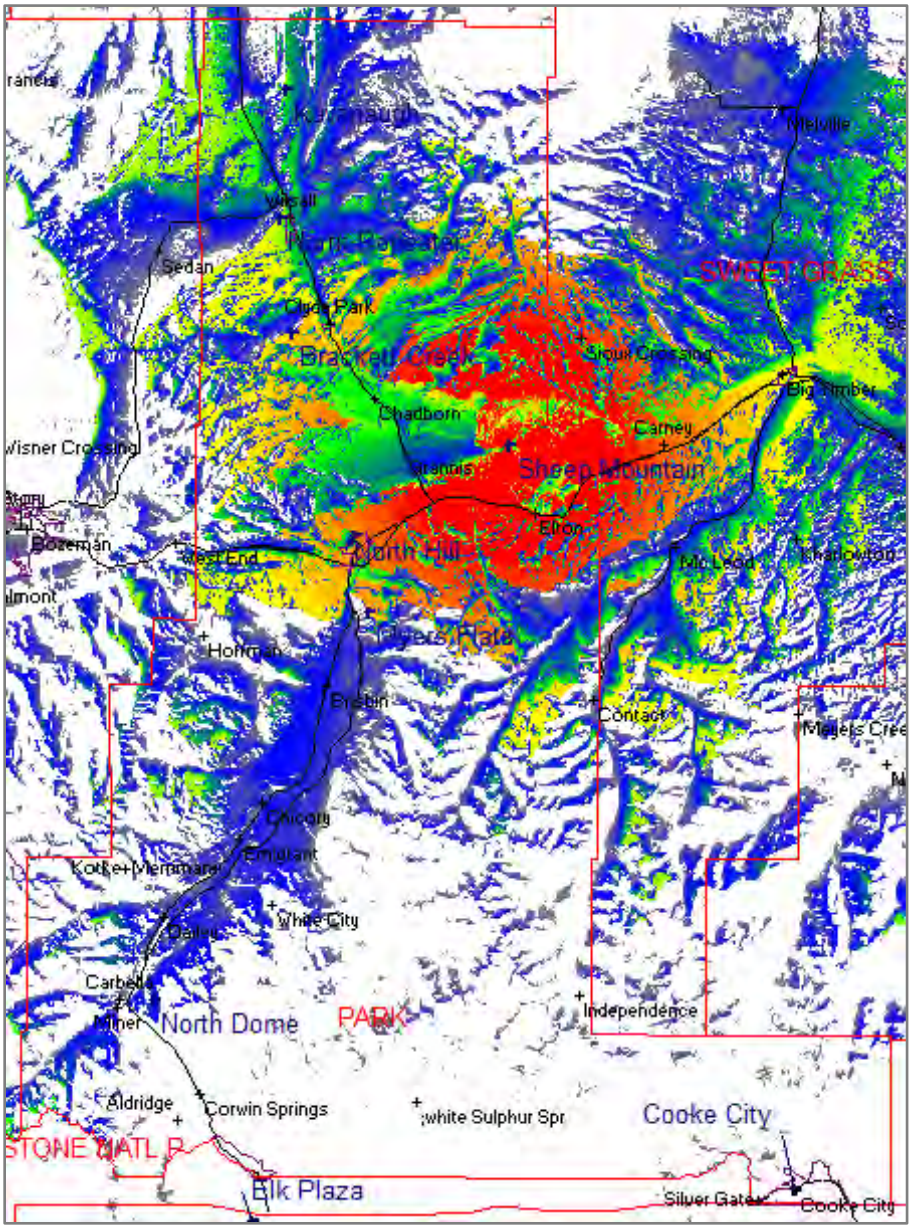


FIGURE 37
Sheep Mountain Talk-Out Coverage Prediction

- **North Hill**: This proposed radio site is required for primary street level and in-building radio coverage into the City of Livingston, along I-90 from approximately exit 330 to exit 340, U.S. 89 from approximately Old Clyde Park Road to Cedar Bluffs Road, the north facing slopes of Canyon Mountain, and the north facing foothills of Meyers Flats/ Livingston Peak. This site is recommended as a transmitter and voted receiver site for public safety communications. The coordinates of the site are 45° 40′ 25.9″ N, 110° 34′ 02.9″ W (NAD83) at an elevation of approximately 4,890 feet AMSL (see Appendix C, Photograph NH-2).

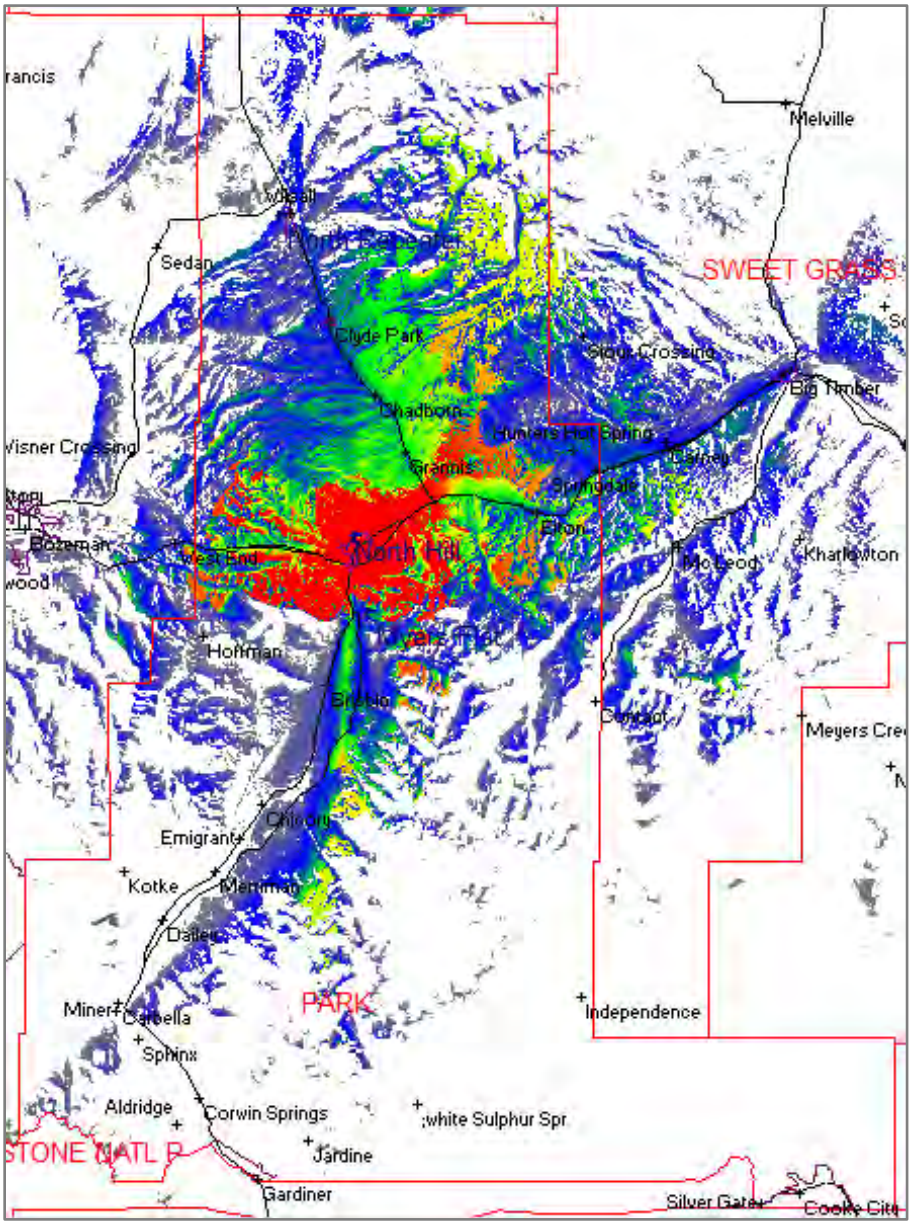


FIGURE 38
North Hill Talk-Out Coverage Prediction

- **North Dome**: This proposed radio site is required for primary radio coverage along U.S. 89 from approximately Emigrant south to Papesh Road 4 miles northwest of Gardiner, Big Creek Road, Rock Creek Road, and Tom Miner Creek Road. The coordinates of the site are 45° 12′ 28.2″ N, 110° 51′ 22.6″ W (NAD83) at an elevation of approximately 7,755 feet AMSL (Appendix C, Photograph ND-1).

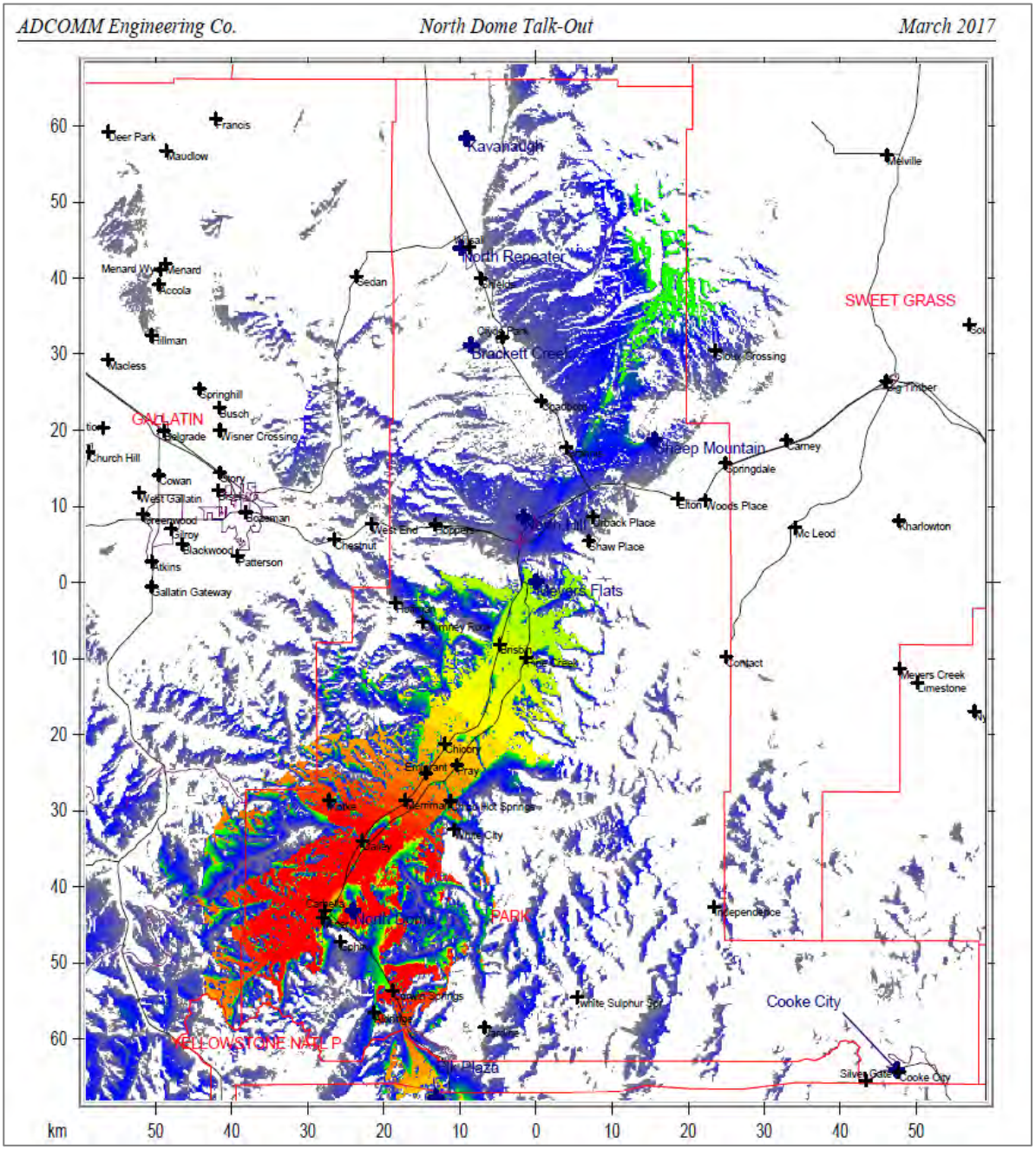


FIGURE 39
North Dome Talk-Out Coverage Prediction

- **Elk Plaza (Wyoming)**: This proposed radio site is required for primary street level and in-building radio coverage into the Community of Gardiner, along U.S. 89 from approximately Maiden Basin Road to Lava Creek Campground on the Yellowstone National Park Grand Loop Road heading towards Silver Gate/Cooke City. Mobile coverage will be available approximately from Lava Creek Campground to Blacktail Plateau Drive continuing on the Yellowstone National Park Grand Loop Road heading towards Silver Gate/Cooke City. This site is recommended as a transmitter and voted receiver site for law enforcement public safety communications. The coordinates of the site are 44° 59′ 11.7″ N, 110° 42′ 57.0″ W (NAD83) at an elevation of approximately 6,824 feet AMSL (see Appendix C, Photograph EP-1).

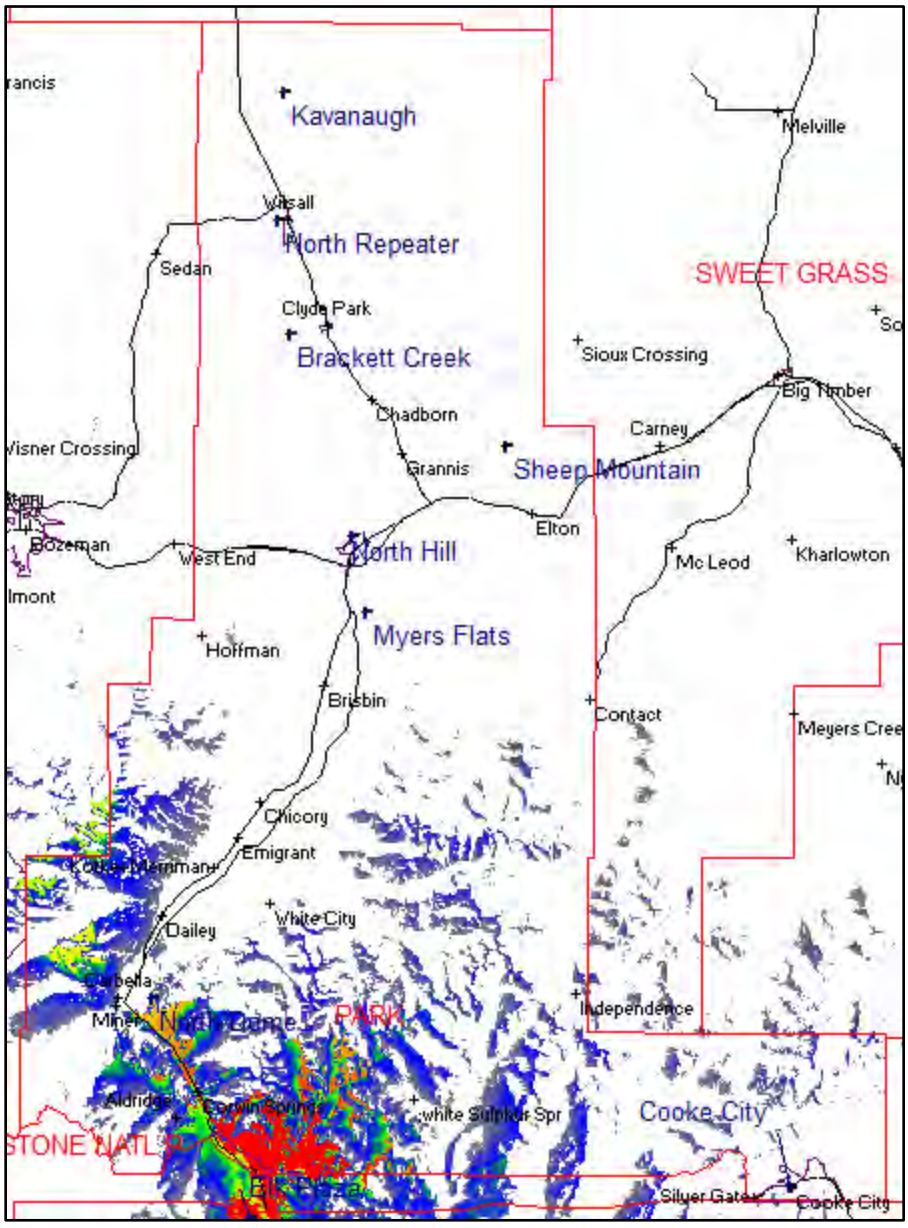


FIGURE 40
Elk Plaza Talk-Out Coverage Prediction

- **Cooke City Fire Station**: This proposed radio site is required for primary street level radio coverage into the Community of Silver Gate, and street level and in-building radio coverage into the Community of Cooke City, along U.S. 212 from approximately the Montana and Wyoming state line to approximately the Clarks Fork Picnic Area access road. This site is recommended as a repeater site for law enforcement public safety communications. The coordinates of the site are 45° 01′ 9.5″ N, 119° 56′ 10.9″ W (NAD83) at an elevation of approximately 7,572 feet AMSL (Photograph CC-1).

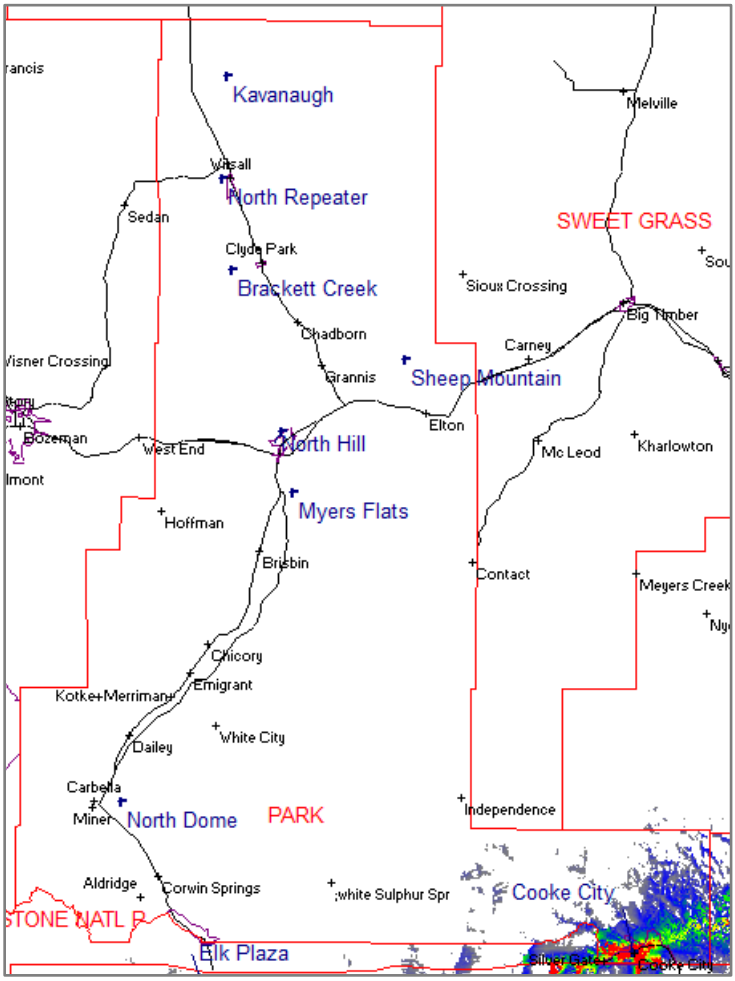


FIGURE 41
Cook City Fire Station Talk-Out Coverage Prediction

Other candidate sites were researched and preliminary coverage maps were developed but not listed in the report.

Location ID	Coverage Target Within County	Location Type	Latitude	Longitude	Elevation
Kavanaugh	Northern Border	Existing Site	46° 07' 21.7" N	110° 39' 51.8" W	5,911 feet
Brackett Creek Overlook	Clyde Park and Surrounding Area	Developed Area*	45° 52' 40.2" N	110° 39' 24.0" W	5,470 feet
Sheep Mountain	County East Central	Existing Site	45° 45' 56.5" N	110° 20' 46.8" W	6,220 feet
North Dome	County Southwest	Existing Site	45° 12' 28.2" N	110° 51' 22.6" W	7,755 feet
Elk Plaza	Gardiner and Surrounding Area	Existing Site	44° 59' 11.7" N	110° 42' 57.0" W	6,824 feet
Cooke City Fire Station	Cooke City and Silver Gate	Existing Site	45° 01' 9.5" N	109° 56' 10.9" W	7,572 feet

Backcountry and Search and Rescue Coverage

The PCSO interviews and ride-alongs identified poor or non-existing two-way radio dispatch coverage along transportation routes and common SAR staging or base camp areas. Today, a relay vehicle and a radio operator would typically be set up to relay voice traffic into a poor radio coverage area. SAR is also capable of deploying their portable repeater to a mountaintop location to improve radio coverage in a particular area. Providing dispatch coverage into areas that may have a few calls a year would be expensive to design, build, and operate.

In these special cases, one of ADCOMM's recommendations is to deploy an interoperability satellite communications solution that can directly connect to the dispatch console or to the main law enforcement VHF channel to allow en route and local SAR staging or base camp VHF communications back to dispatch.

Recent mobile satellite communications technology has made significant interoperability improvements to extend VHF radio communications into remote areas at a very reasonable cost. Additional information can be found in the technology review and recommendations report.

Channel Plan and Coverage Expansion Recommendations

Each of the three proposed channels (Law, County Fire, and Livingston Fire) will use different radio sites and different technologies to provide the necessary coverage; coverage will be expanded through a phased approach. The sites and technology recommended for each channel are detailed in this section.

Transmitter steering is the initial recommended technology to improve fire coverage. Transmitter steering meets the initial need for wide area dispatch coverage with localized fire user communications. Site can be added with the challenge of intermediate simulcast optimization. This technology can eventually be transitioned to simulcast once funding becomes available and site expansion is completed.

Multicast is the initial recommended technology to improve law coverage. Multicast meets the need for wide area dispatch coverage and wide area end user coverage. This technology can eventually be transitioned to simulcast once funding becomes available and site expansion is completed.

Table 15 summarizes the proposed channel plan by site, technology and phase.

TABLE 15
Locations of Sites per Channel per Phase (Locations Listed from North to South)

Improvement Phase	County Fire	Livingston Fire	Law
Technology Strategy Phases 1-3	Transmitter Steering	Transmitter Steering	Voted Multicast
Phase 1	North Hill Meyers Flats Wilsall Mountain	North Hill Meyers Flat	North Hill Meyers Flat
Phase 2	Sheep Mountain North Dome	Continue As-Is	Sheep Mountain North Dome Cooke City
Phase 3	Kavanaugh Brackett Creek Wilsall Mountain (Relocated to Mercury Tower)	Continue As-Is	Kavanaugh Brackett Creek Wilsall Mountain (Relocated to Mercury Tower) Elk Plaza
Phase 4 Long Term	Voted Simulcast	Voted Simulcast	Voted Simulcast

See Figure 42 for County Fire site locations. See Figure 43 for Livingston Fire site locations. See Figure 44 for Law site locations.

FIGURE 42
Proposed Sites for County Fire Dispatch

FIGURE 43
Proposed Sites for Livingston Fire Dispatch

Numbers represent the recommended phase to implement the site.
Black squares in left map (County Fire) represent additional proposed sites for County Law.
Black squares in right map (Livingston Fire) represent proposed sites for County Fire and County Law.

FIGURE 44
Proposed Sites for Law Dispatch

Numbers represent the recommended phase to implement the site.
Black squares represent proposed sites for other two channels.

Backhaul Recommendations

The proposed radio system will require connectivity between the various remote radio sites, centralized control equipment, and dispatch center. Point-to-point connectivity can be provided by microwave, 900 MHz, or narrowband UHF links; each link type listed is a tradeoff between cost and capacity. The technology recommended for each site is detailed in this section.

High-bandwidth low-latency point-to-point connections are recommended for all sites, except Cooke City. High-bandwidth connections provide bandwidth for sites with multiple radio channels and site monitoring traffic. Low-latency is necessary for sites with coverage overlap; it is necessary for optimal receiver voting and required for transmit audio delay synchronization.

960 MHz radio links are a practical cost-efficient solution for Park County. 960 MHz radios are typically fractional T1s, which would provide ample bandwidth for Park County's channel count. Additionally, 960 MHz link radios would be better suited for Park County's rural geography than the higher microwave bands. A commercially provided Internet connection is adequate for Cooke City as there would be no coverage overlap due to geographical obstacles and the radio site would provide highly localized coverage and, therefore, simulcast overlap should not be an issue.

Figure 45 shows the recommended path configuration for the proposed sites.

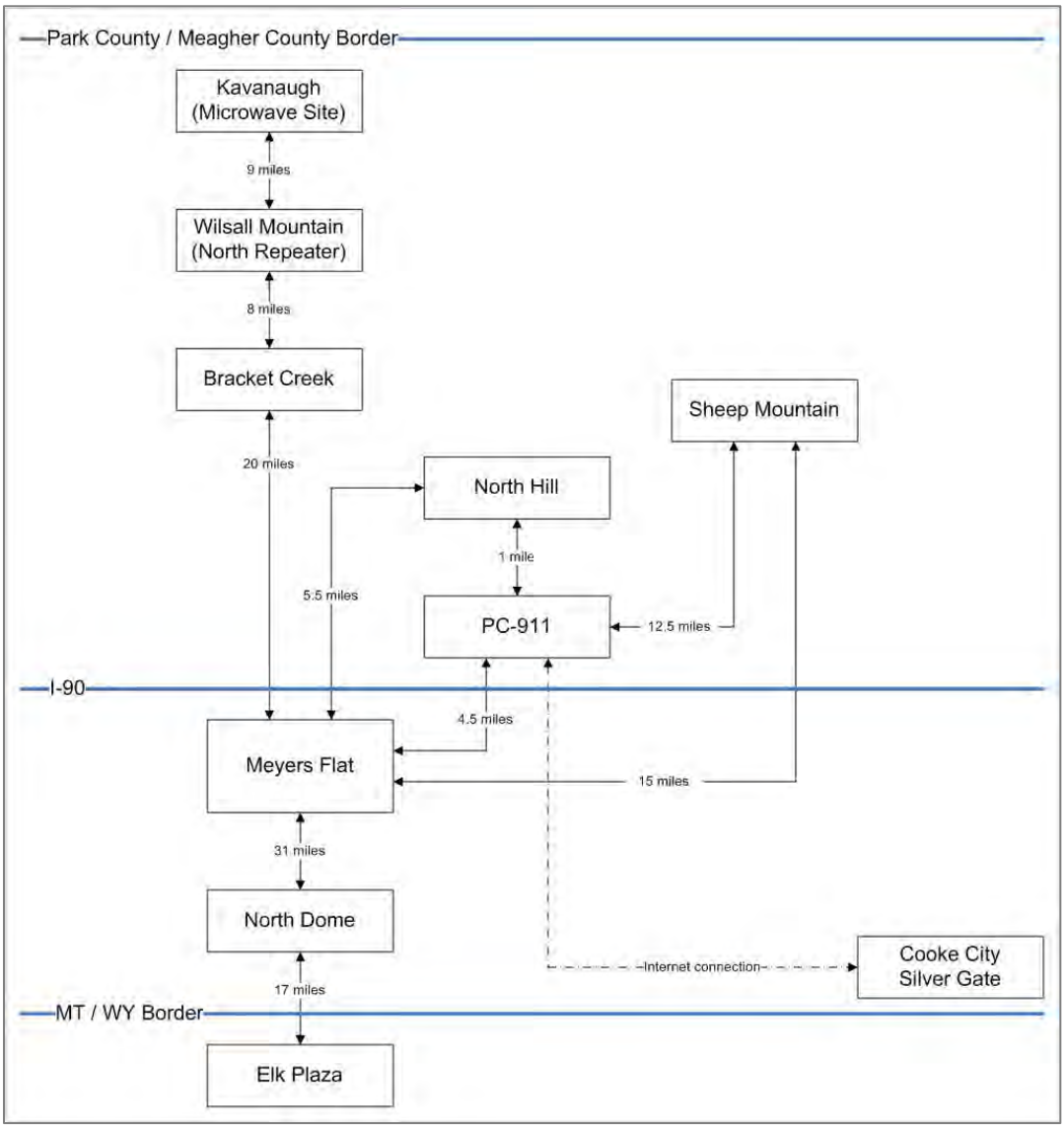


FIGURE 45
Recommended Point-to-Point Link Configuration for Proposed Sites

Budget

When developing the system implementation phases and options, ADCOMM staff considered the potential financial and technical resources available to Park County. Suggesting the county implement, manage, and maintain a $10,000,000 trunked radios system with operating costs in the hundreds of thousands of dollars did not seem realistic for Park County.

As a result, ADCOMM developed a phased approach to allow the county to possibly use a mix of self-generated funds and grant funding. It is important to note the system recommendation is for a conventional analog system, not an APCO Project 25 digital system. However, most grant funds require Project 25 compatibility. However, the grants only require the equipment be Project 25 compatible not that it be operated in the Project 25 mode. Purchasing and operating a Project 25 system will be more expensive than an analog system. In addition, Project 25 systems do not operate as well in rugged mountainous terrain as do analog systems.

Another aspect of operating a system is the system maintenance and management. Project 25 systems are more expensive to manage and maintain. In addition, Project 25 systems require higher levels of technical support and skills in data technology lacking in many rural areas. Analog systems can be easier to implement and maintain than Project 25 digital.

The estimated budget to implement the recommendations in this report is discussed below.

Site Construction

ADCOMM staff chose existing sites wherever possible. It should be noted ADCOMM staff did not determine all of the engineering work required at each site. These are estimates based on experience and site condition. As a result, the estimated site development costs are shown in Table 16.

TABLE 16
Estimated Site Development Costs

Site Name	Description	Cost
Kavanaugh	Existing microwave site. Minor site work estimated.	$30,000
Brackett Creek	New site construction with nearby power lines. A short tower and small building would be installed here. This does not include the cost of the power line.	$115,000
Sheep Mountain	This is an existing site also used by the State of Montana.	$30,000
North Hill	This is an existing site used by Park County. It needs some clean up.	$50,000
North Dome	This is an existing cell site. Minor site work is estimated.	$30,000
Elk Plaza	This is an existing cell and two-way radio site. Minor site work is estimated.	$30,000
Cooke City	The equipment would be installed at the existing fire station. Minor site work is anticipated.	$30,000
	Total Estimated Site Work	**$315,000**

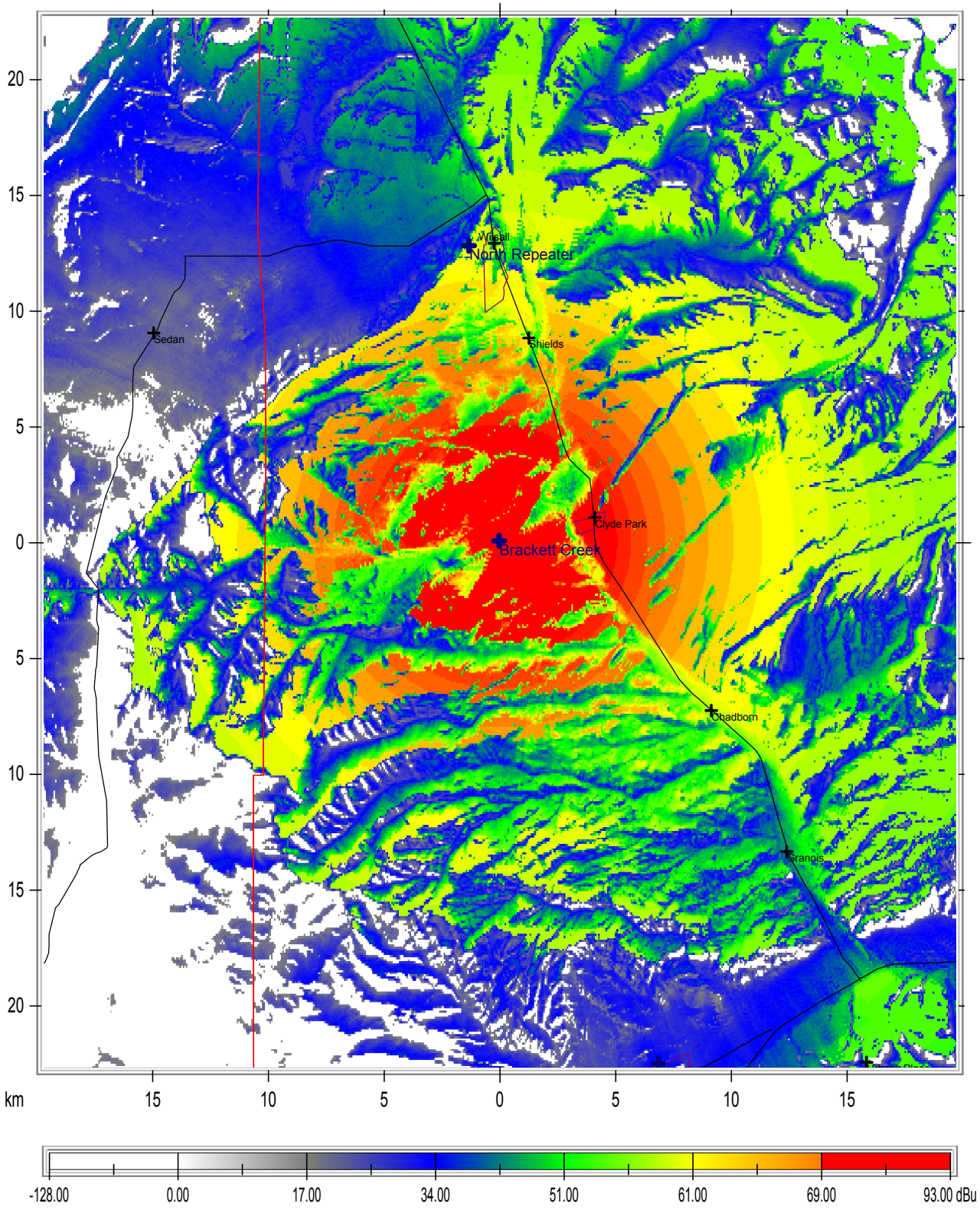
The radio system costs are outlined in Table 17.

TABLE 17
Estimated Radio System Costs

Phase	Law	Fire
1	$250,000	$640,000
2	$235,000	$195,000
3	$300,000	$225,000
4	$180,000	$470,000
Total System Cost	**$965,000**	**$1,530,000**

Note these costs do not include the costs for satellite service or equipment for use in the remote areas. The costs for the satellite service will ultimately be determined by the choice of service provider.

Appendix A
Existing System Coverage Predictions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Wetzel
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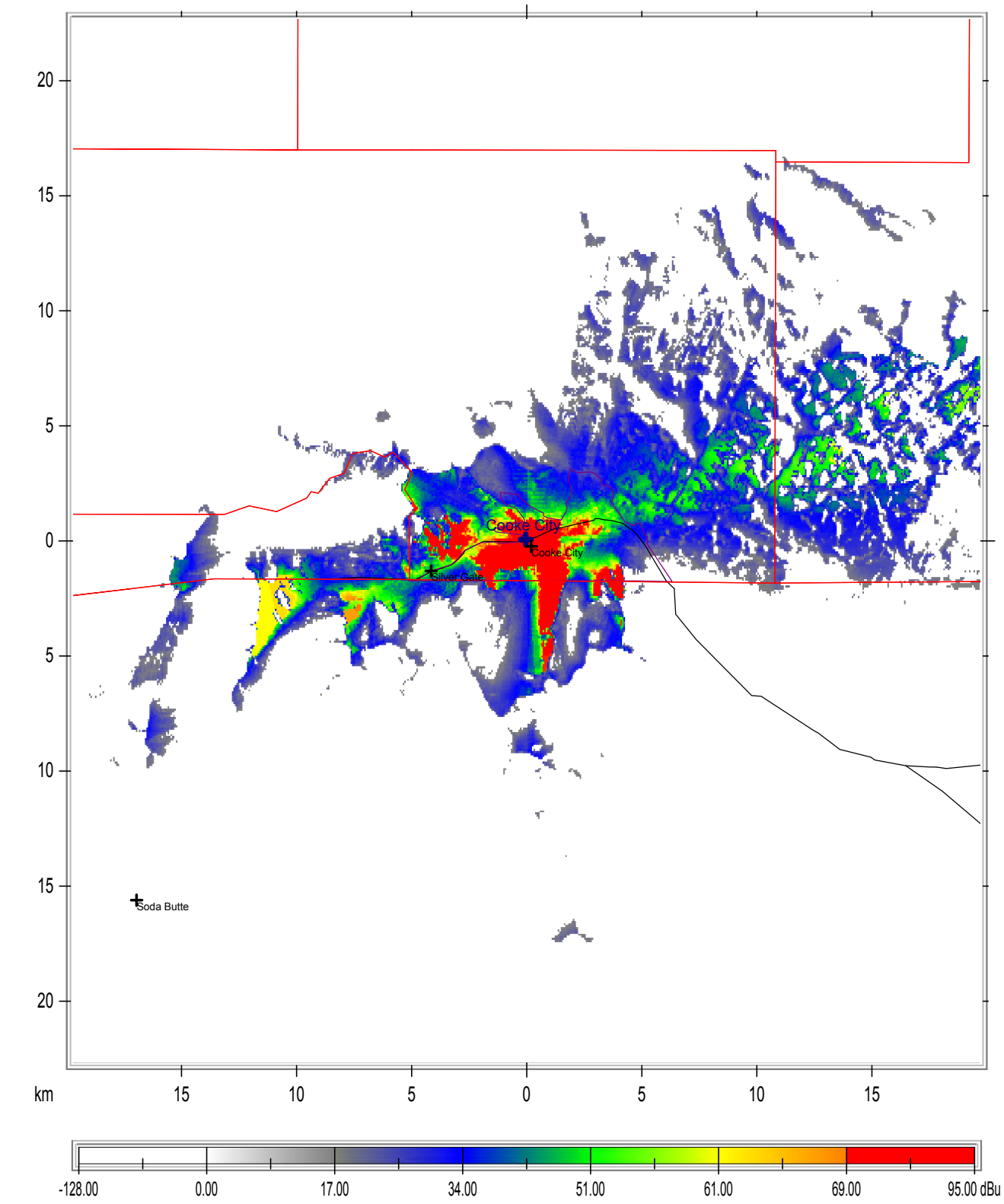
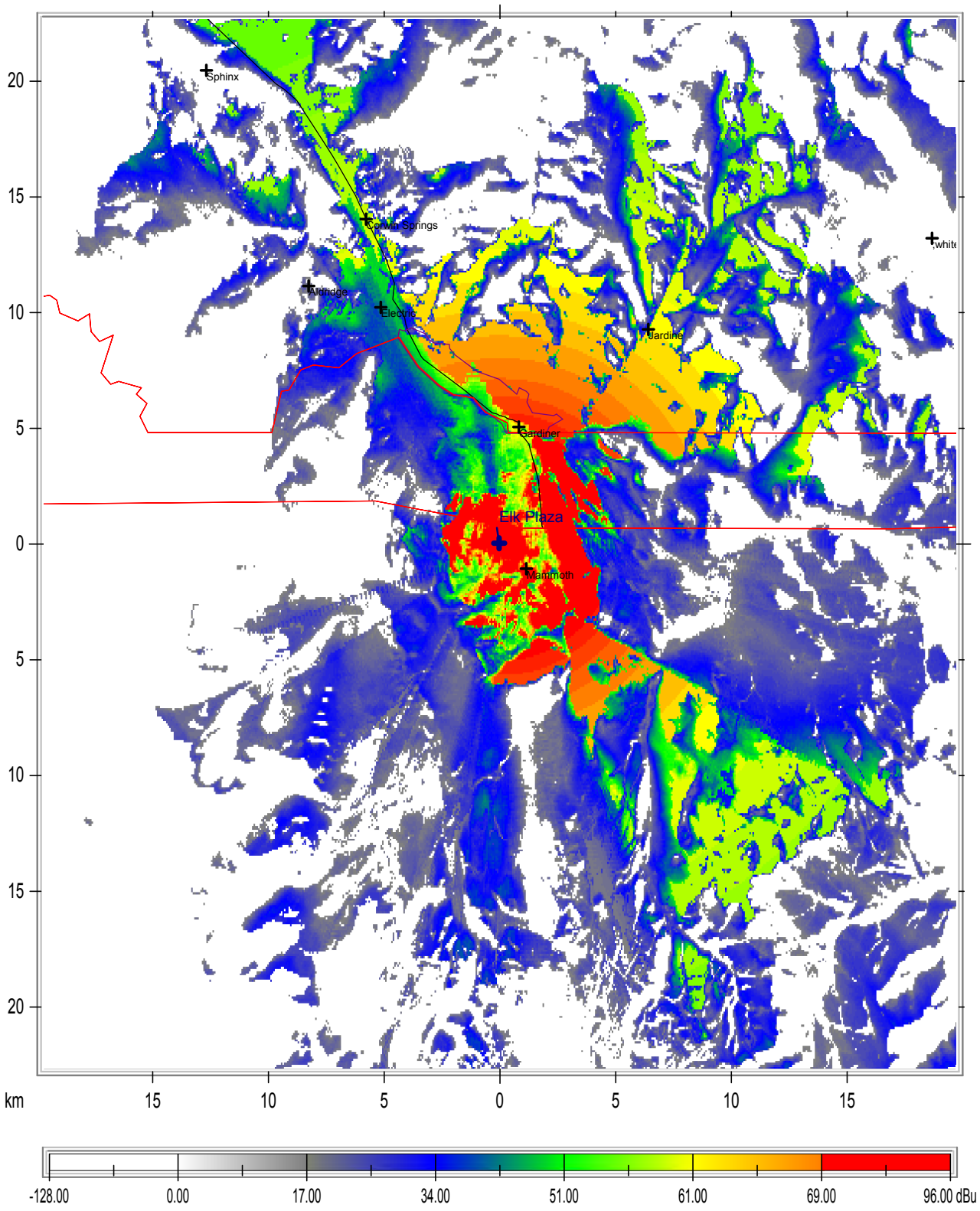
County Borders
City Borders
Highways



Map Scale: 1:250000 1 cm = 2.50 km V|H Size: 45.31 x 39.38 km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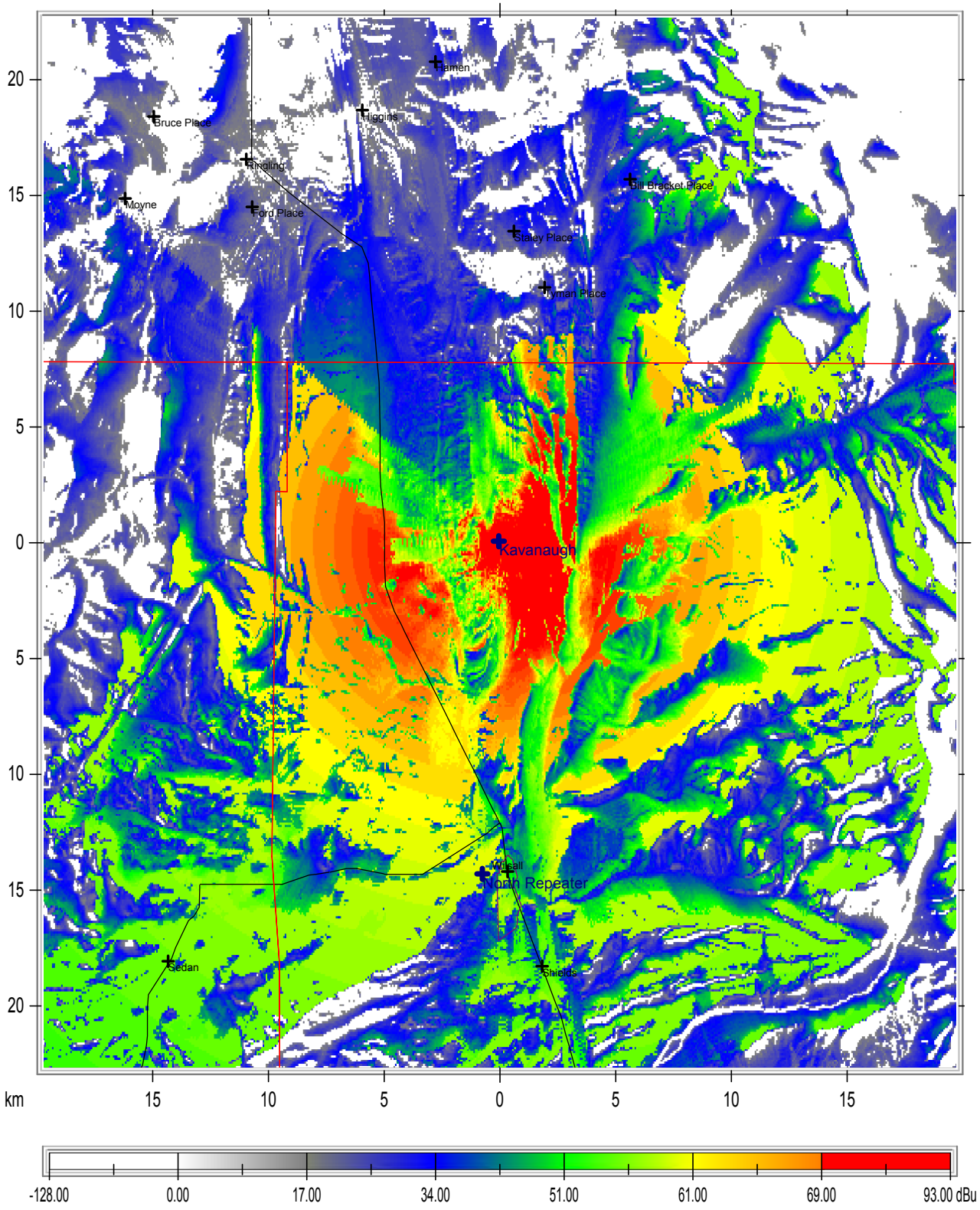
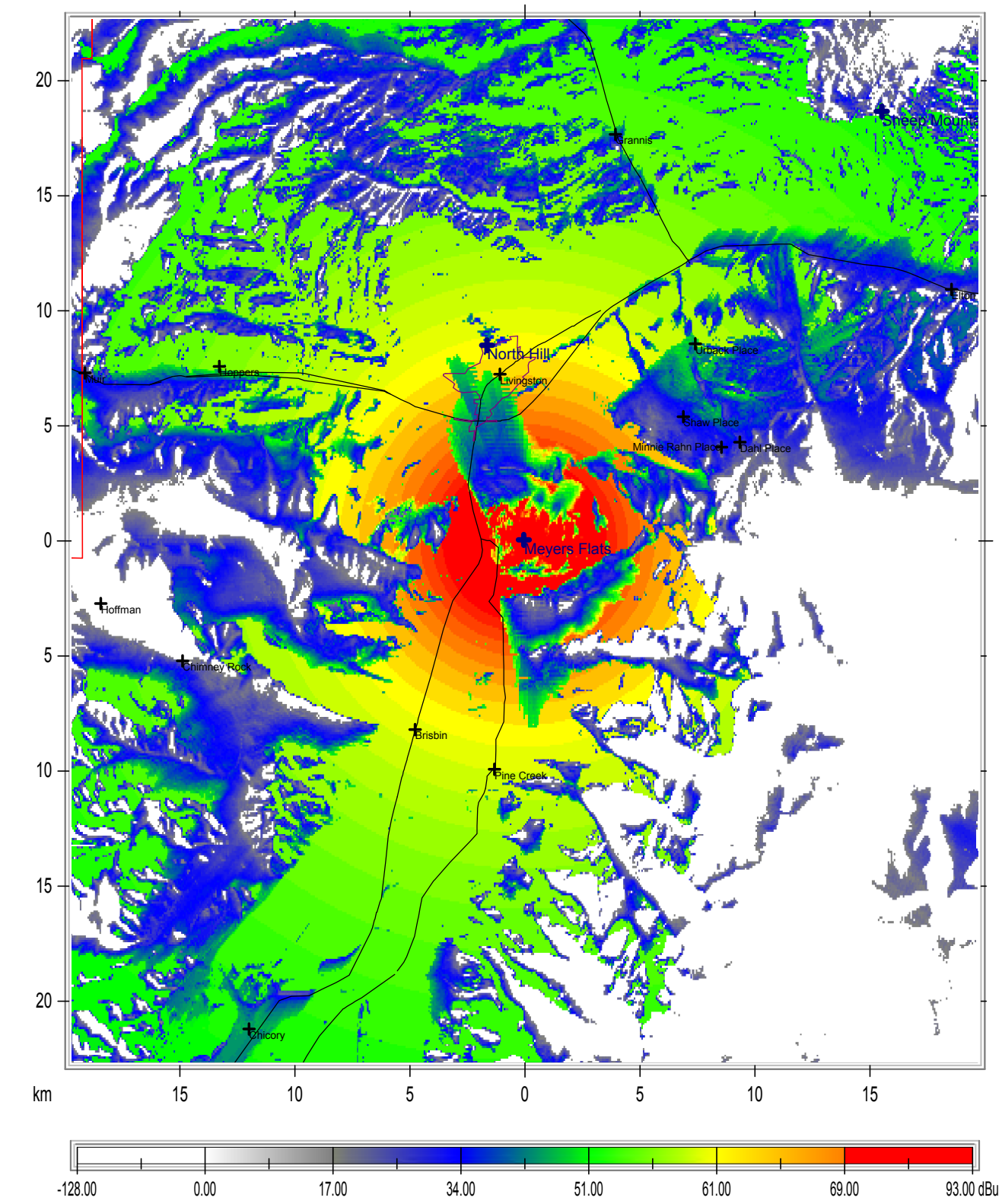
County Borders
City Borders
Highways



Map Scale: 1:250000 1 cm = 2.50 km V|H Size: 45.31 x 39.38 km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North Hill
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Muir
Heppers
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Minnie Rahn Place
Dahl Place
Meyers Flats
Hoffman
Chimney Rock
Brisbin
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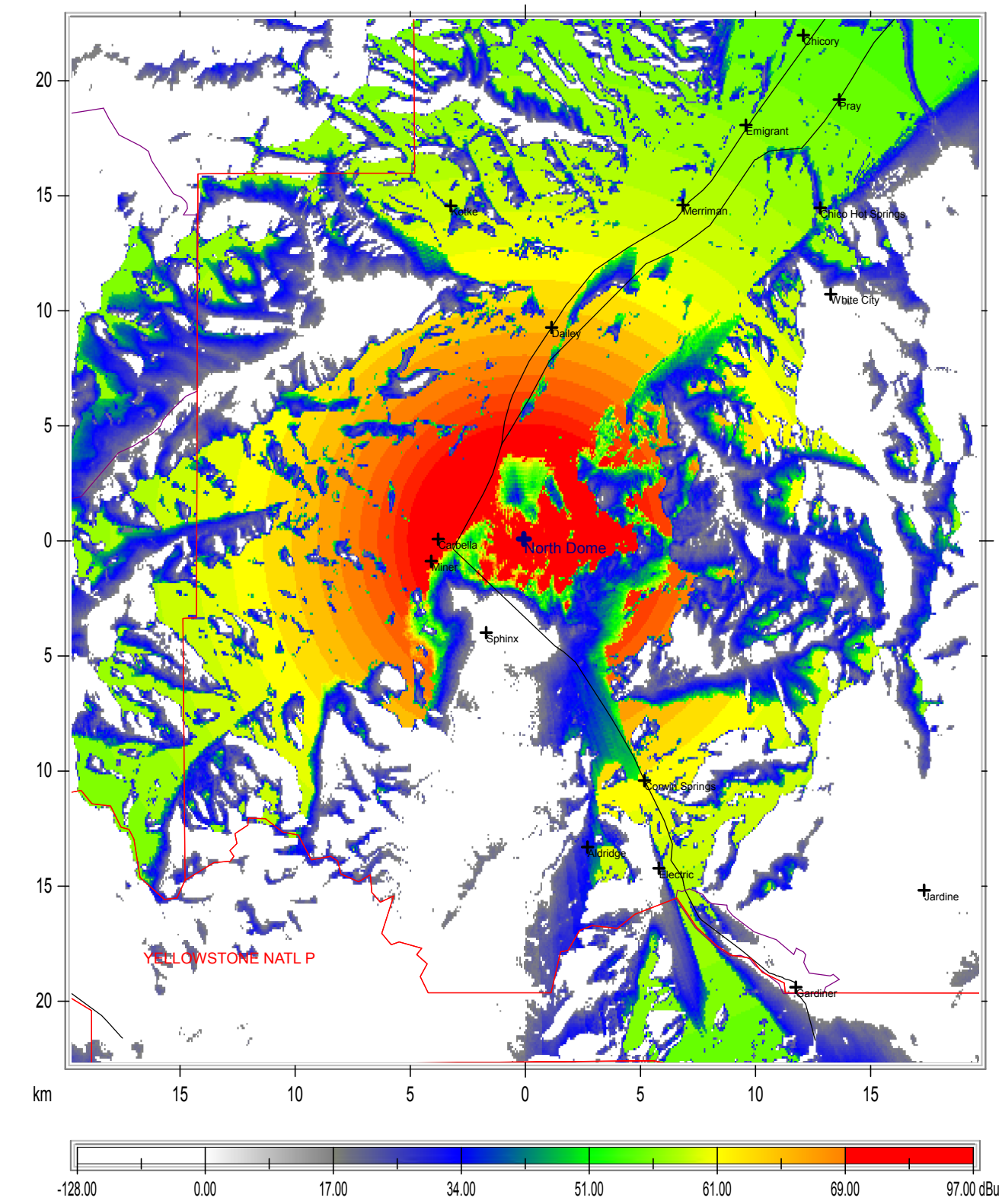

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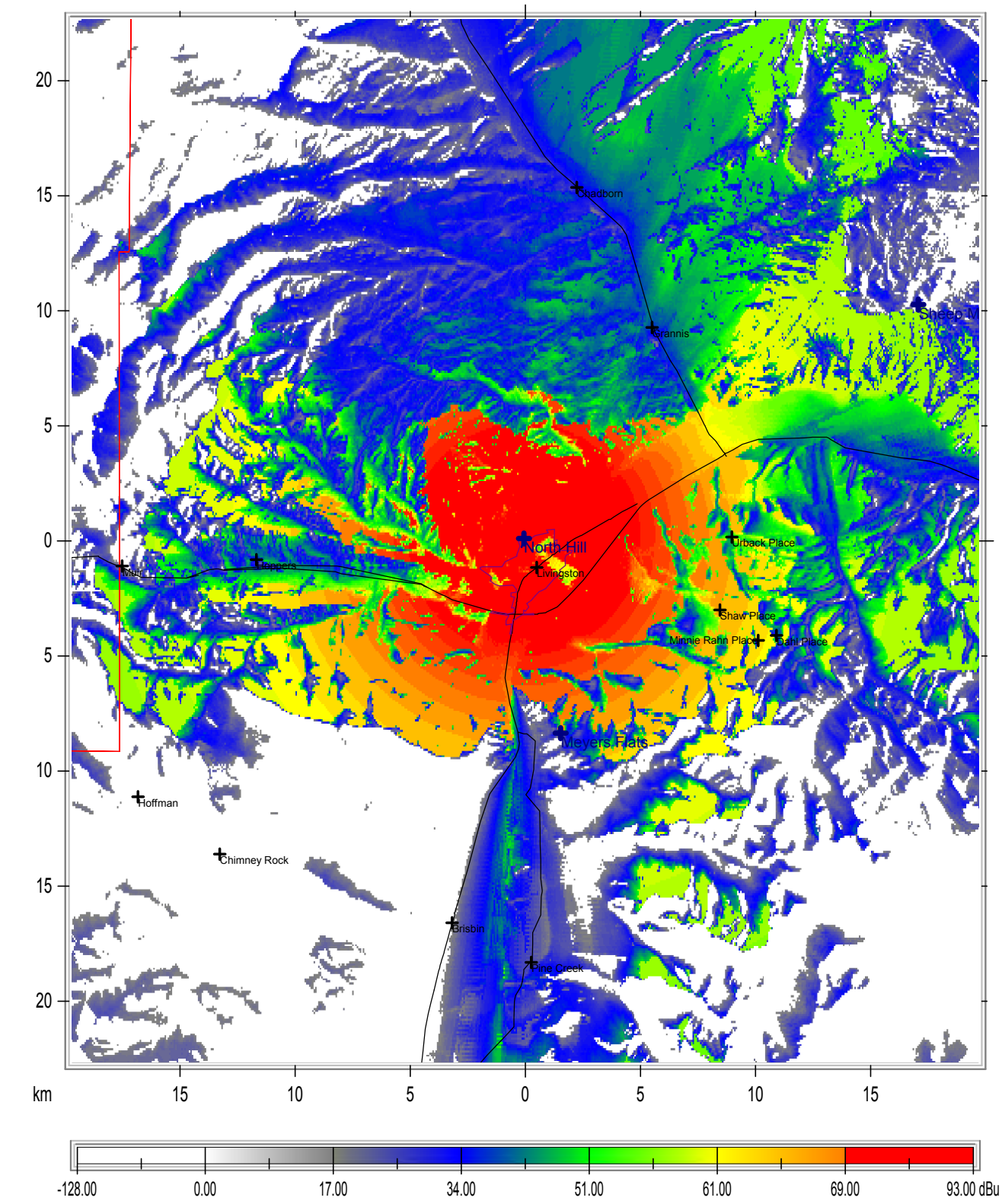

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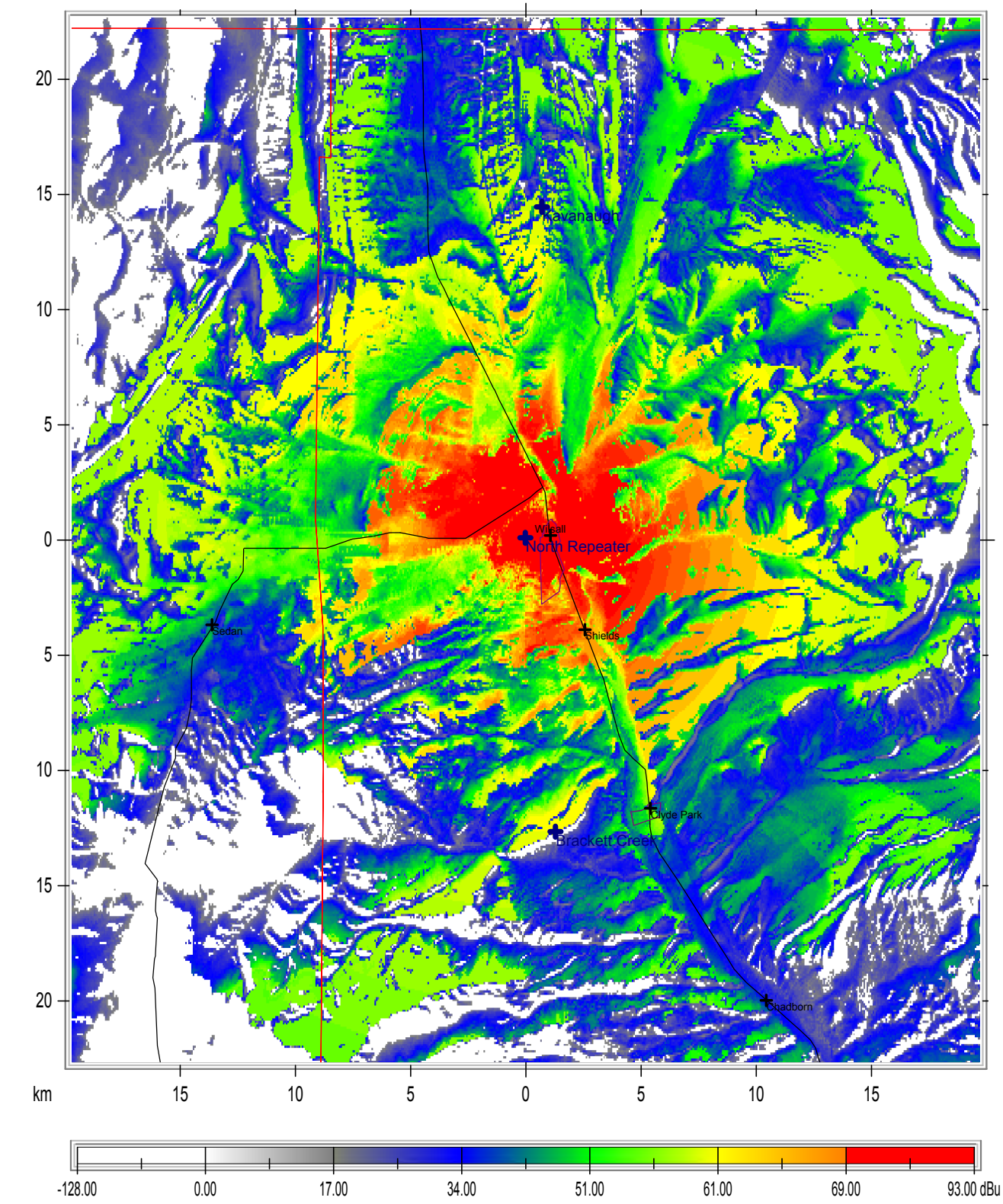
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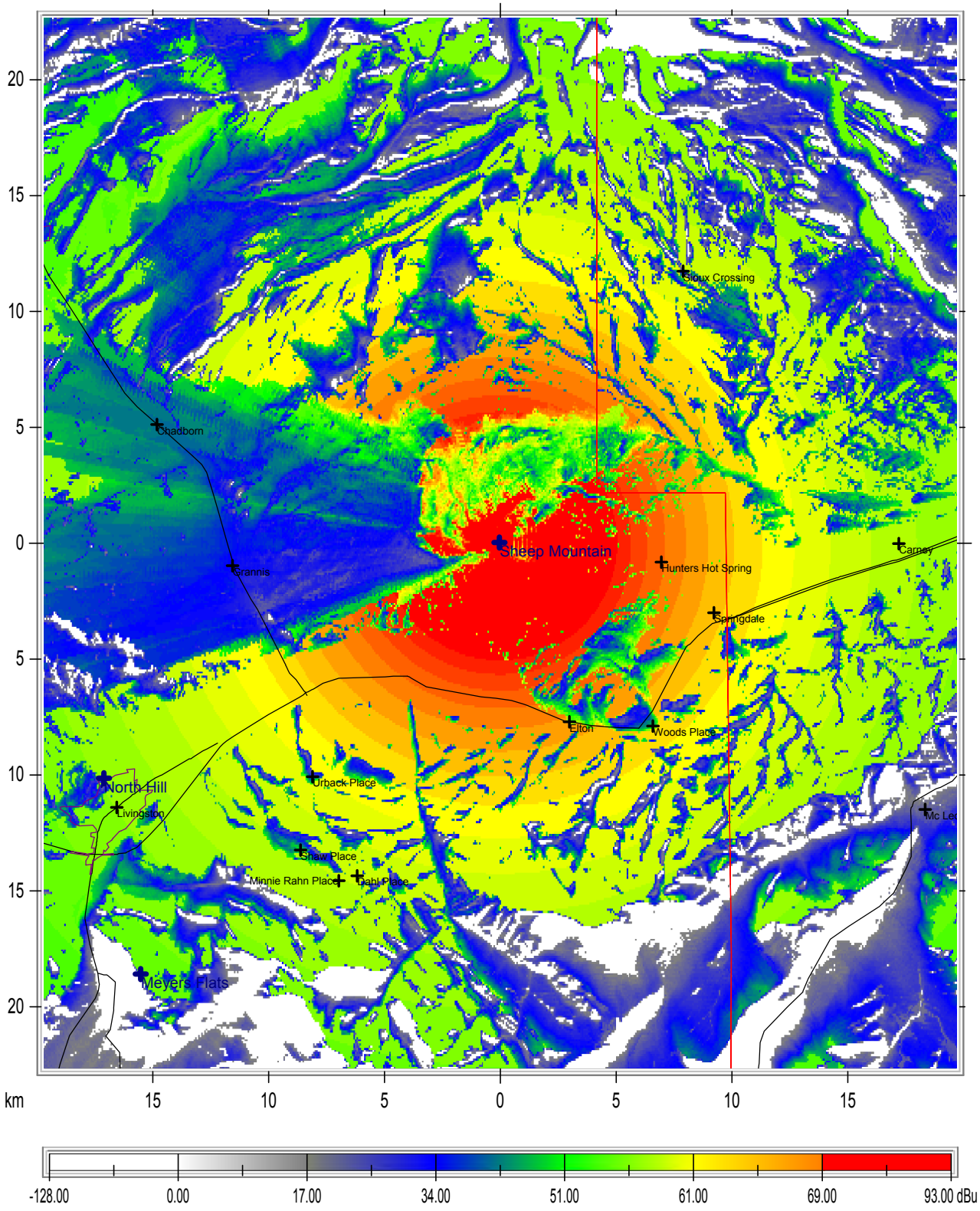
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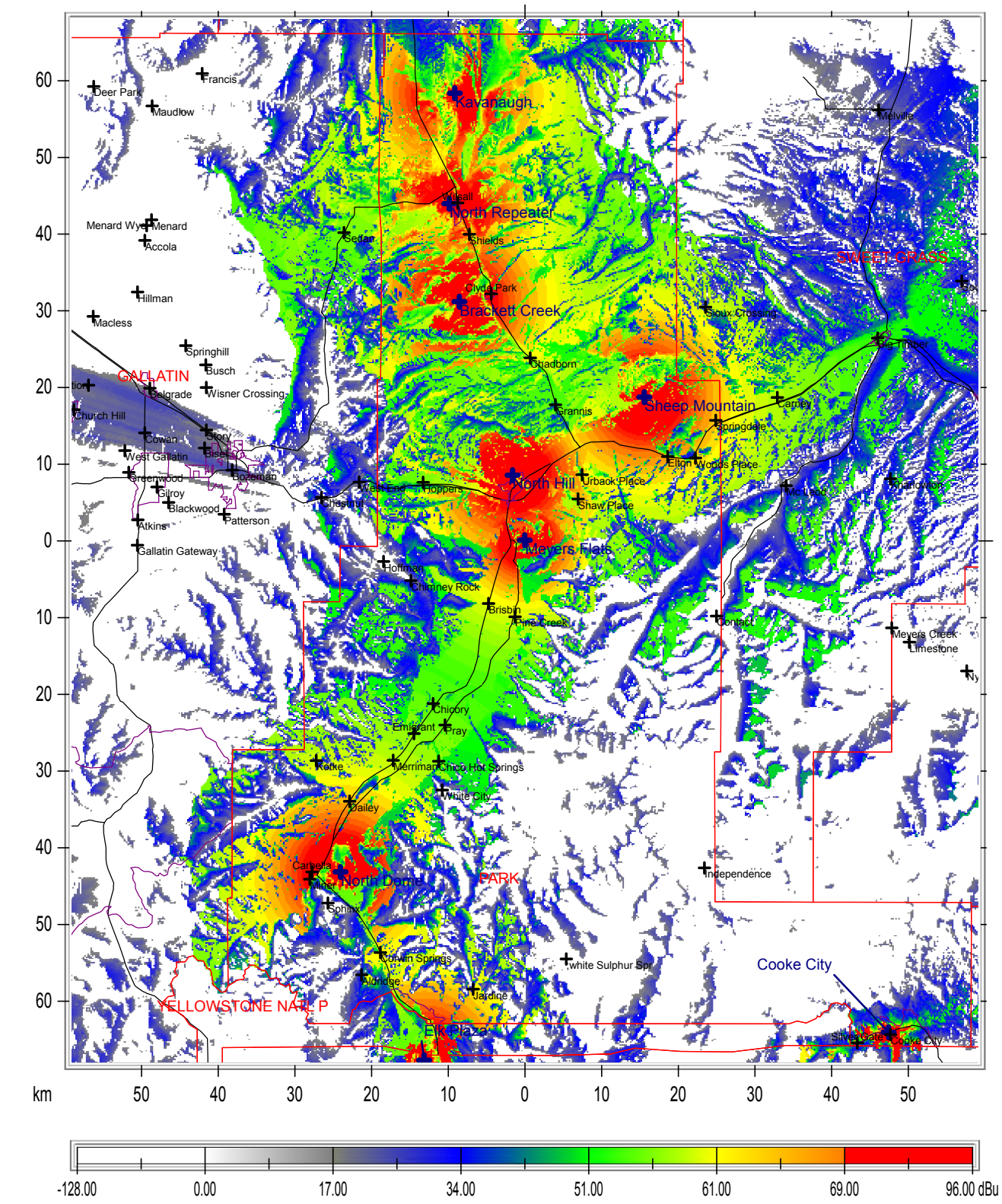
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Cowan
Bisek
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Greenwood
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Chestnut
Hoffman
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Brisbin
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Big Timber
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Martinsdale
Shadowlion
Chicory
Emigrant
Gray
Kelke
Merriman
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White City
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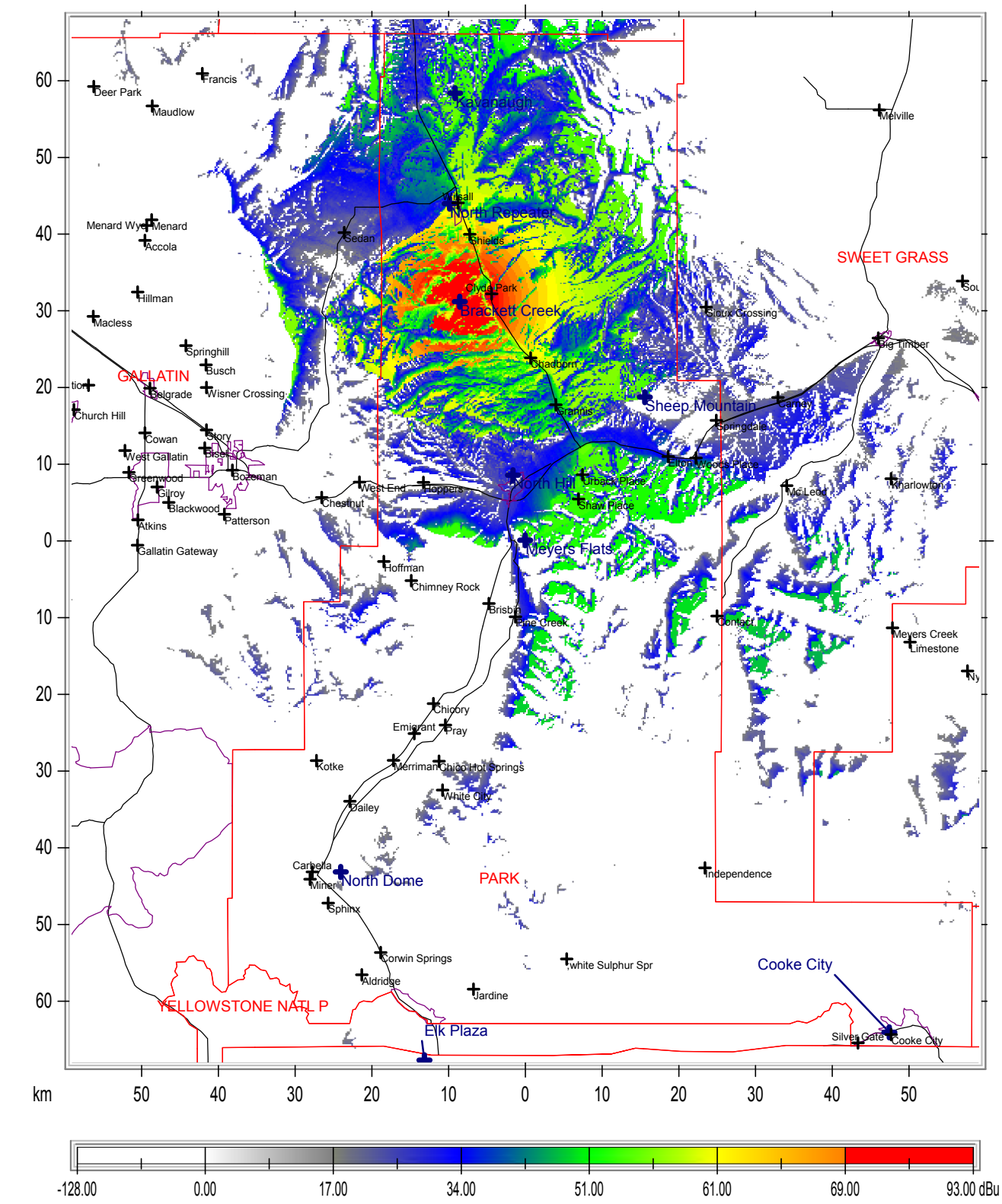
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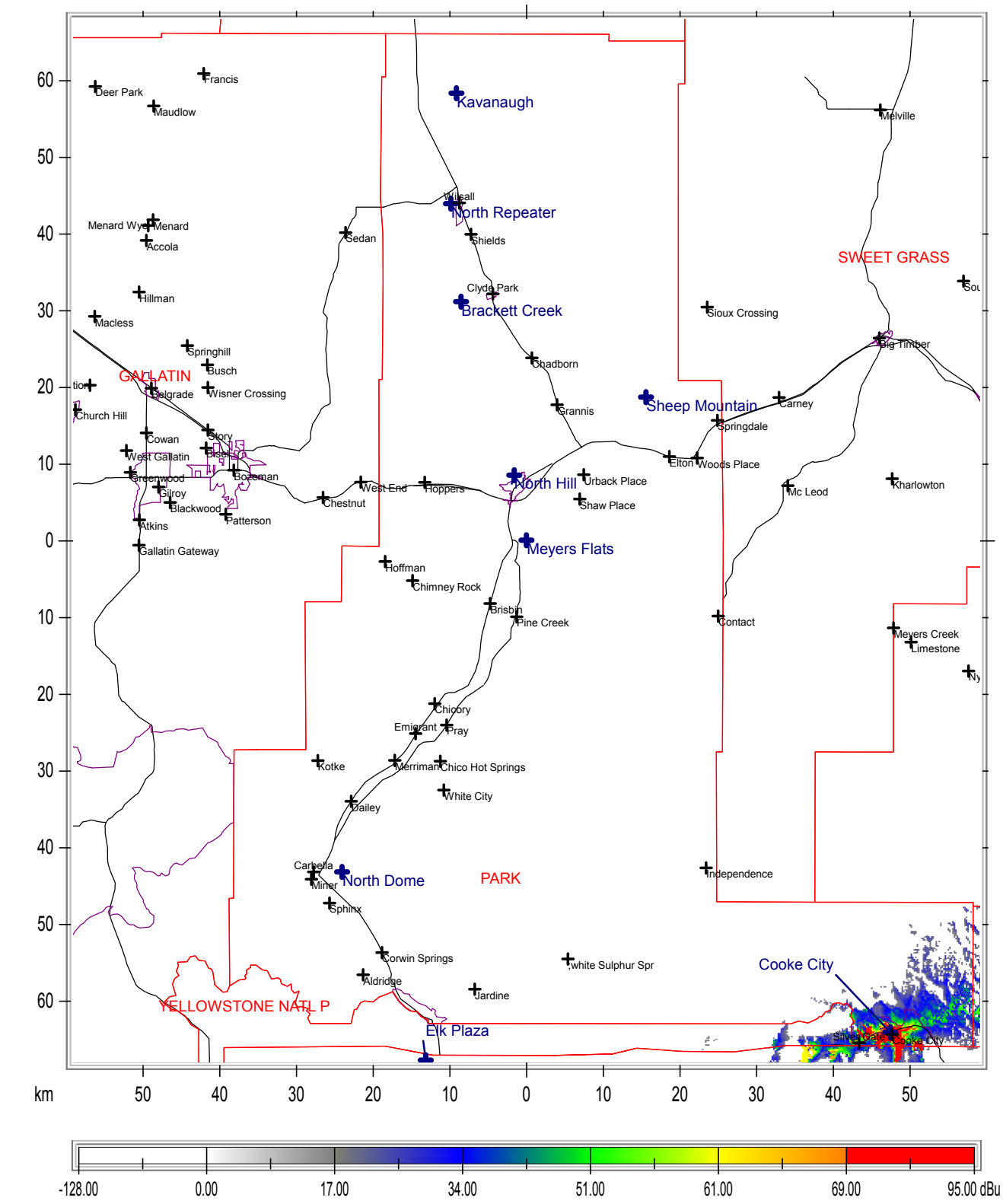
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Church Hill
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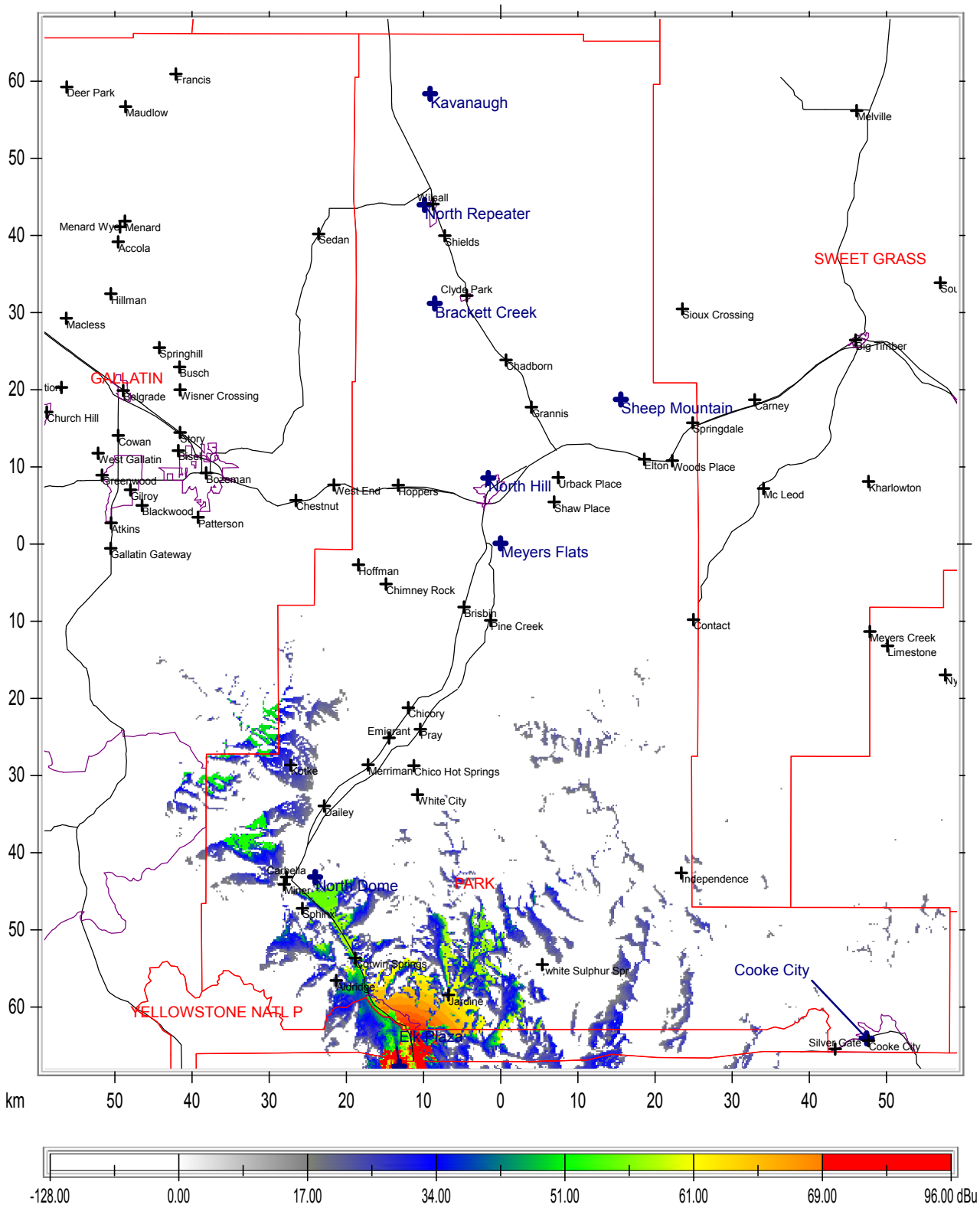
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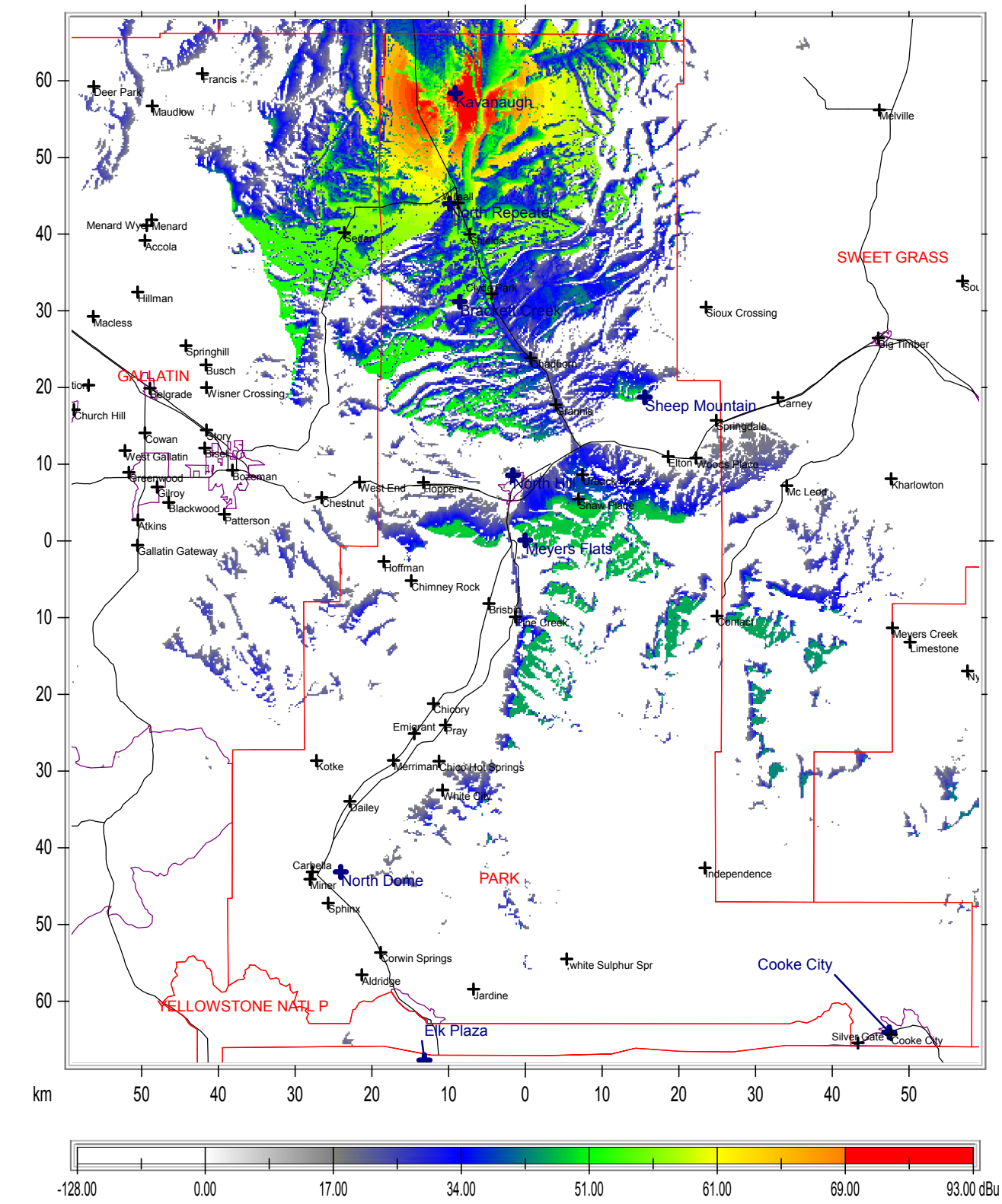
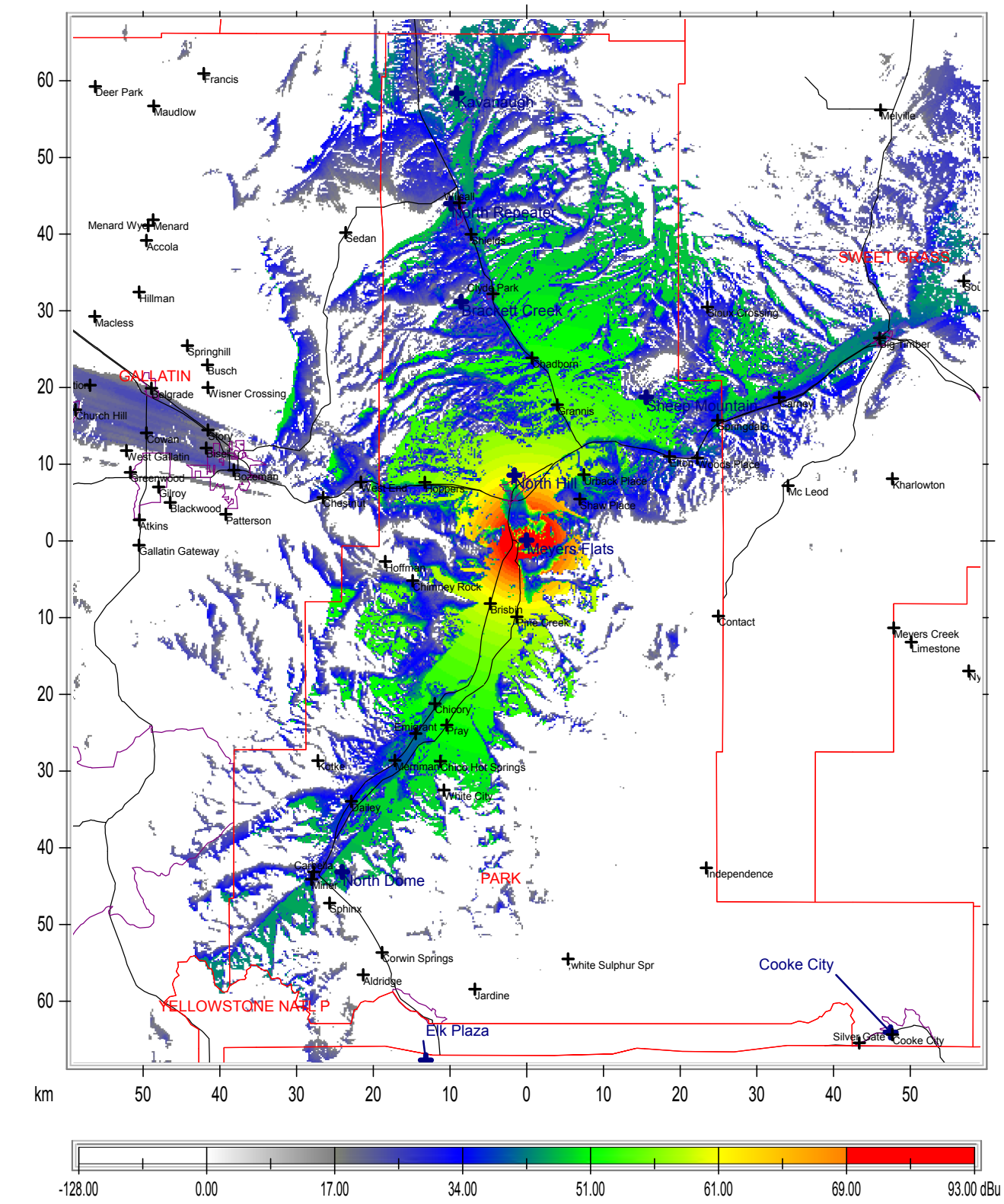


Map Scale: 1:750000 1 cm = 7.50 km V|H Size: 135.93 x 118.13 km



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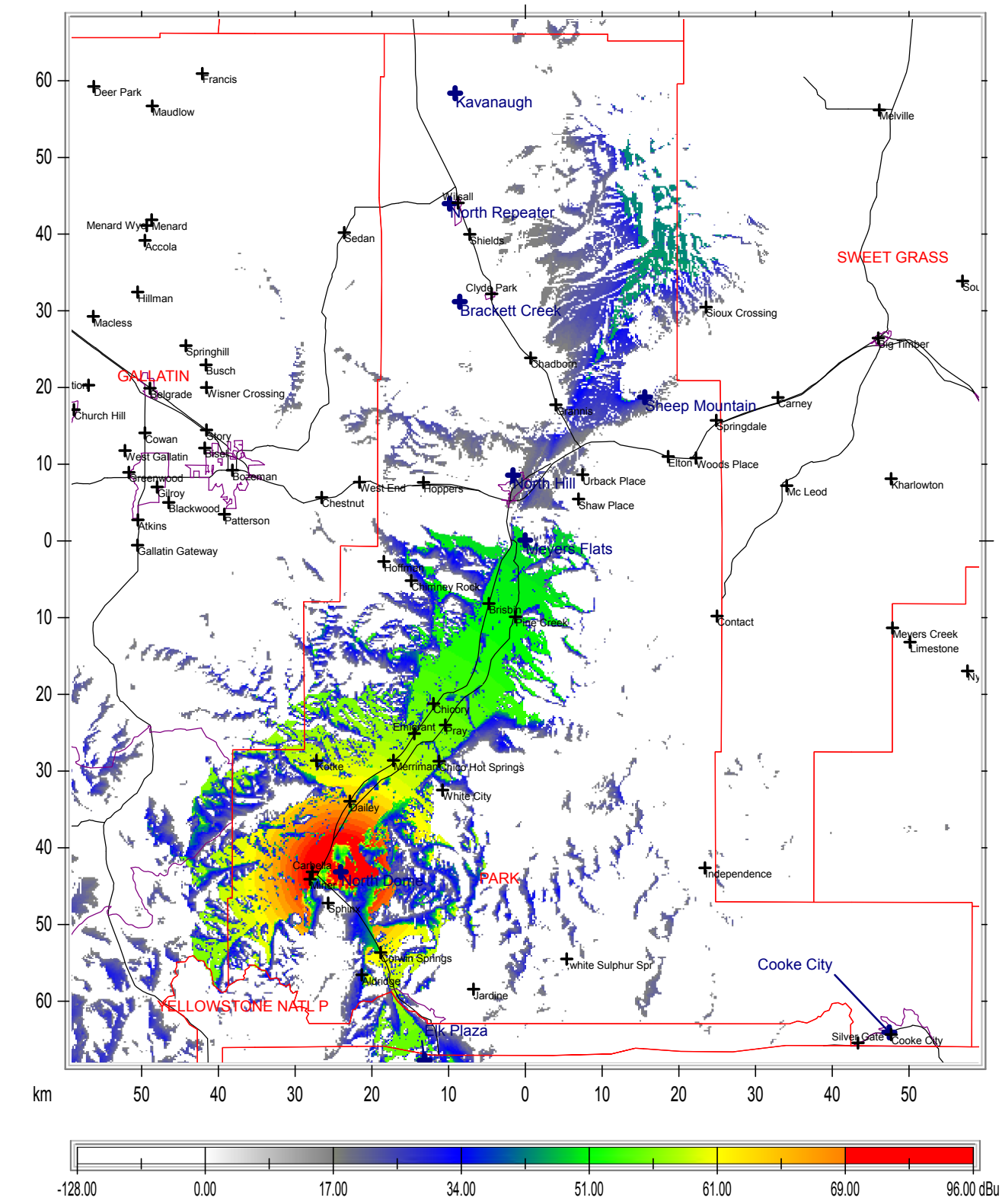
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Church Hill
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Blackwood
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North Hill
Urback Place
Shaw Place
Mc Leod
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Patterson
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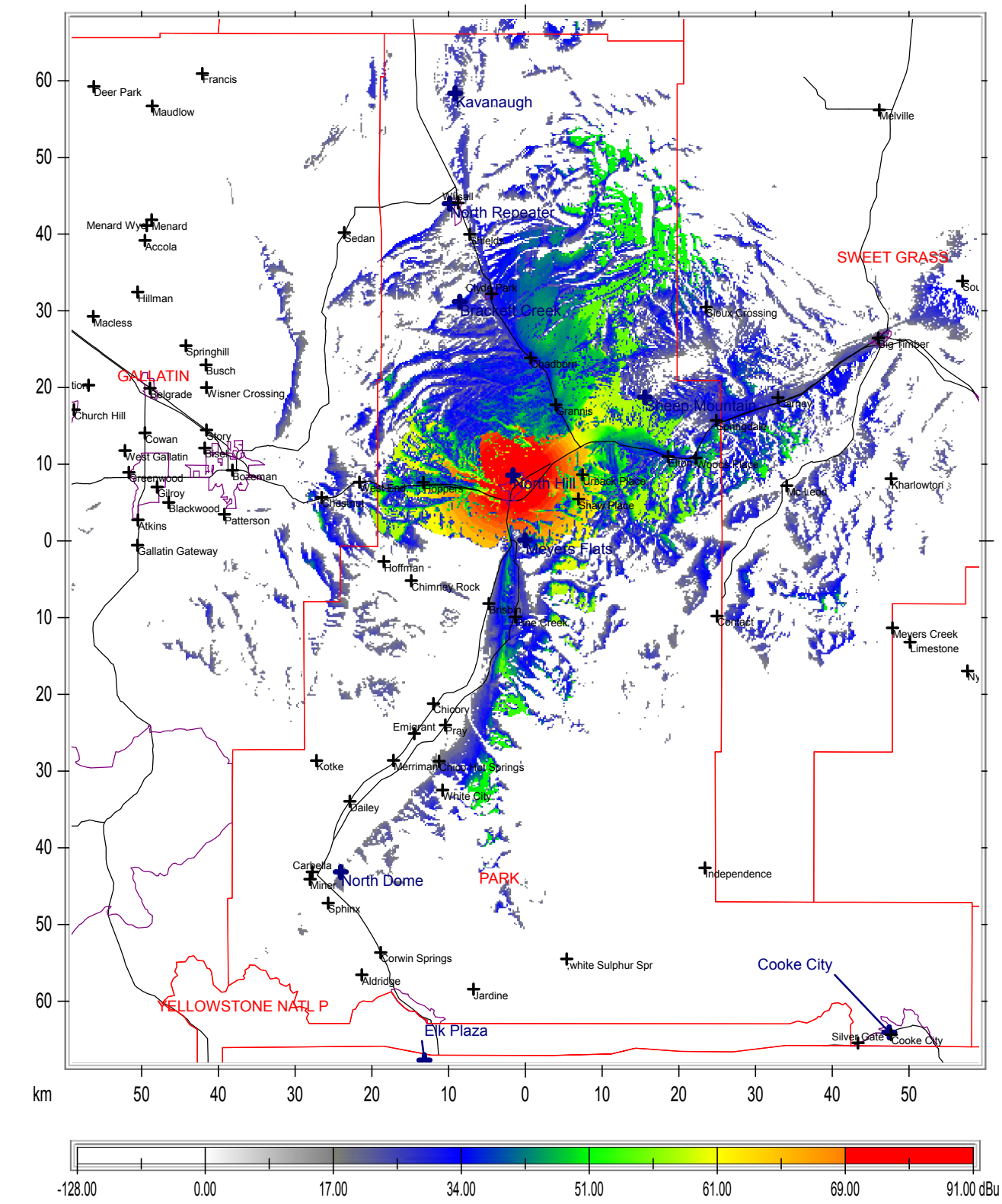
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Hoffman
Chimney Rock
Brisbin
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Meyers Creek
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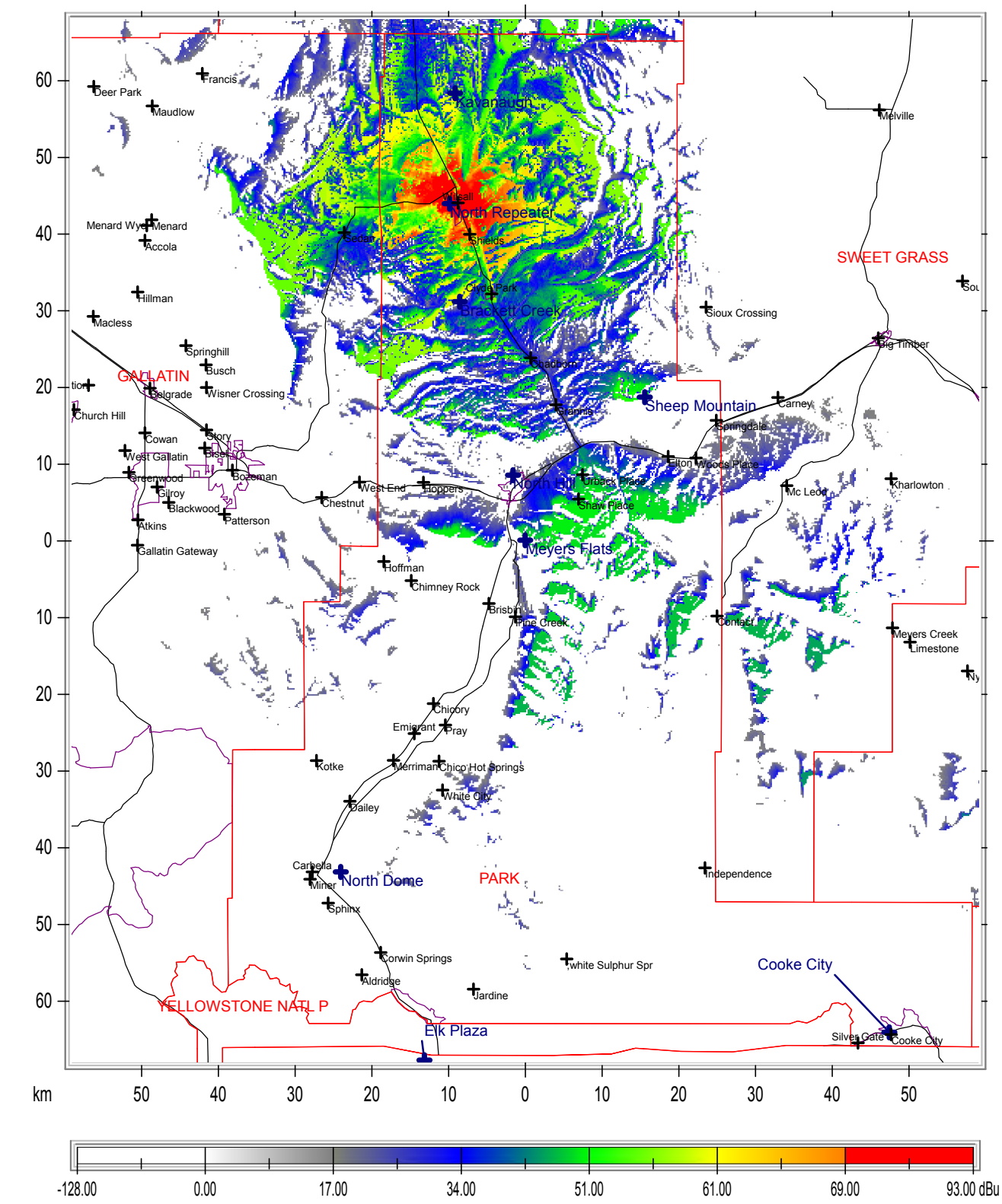

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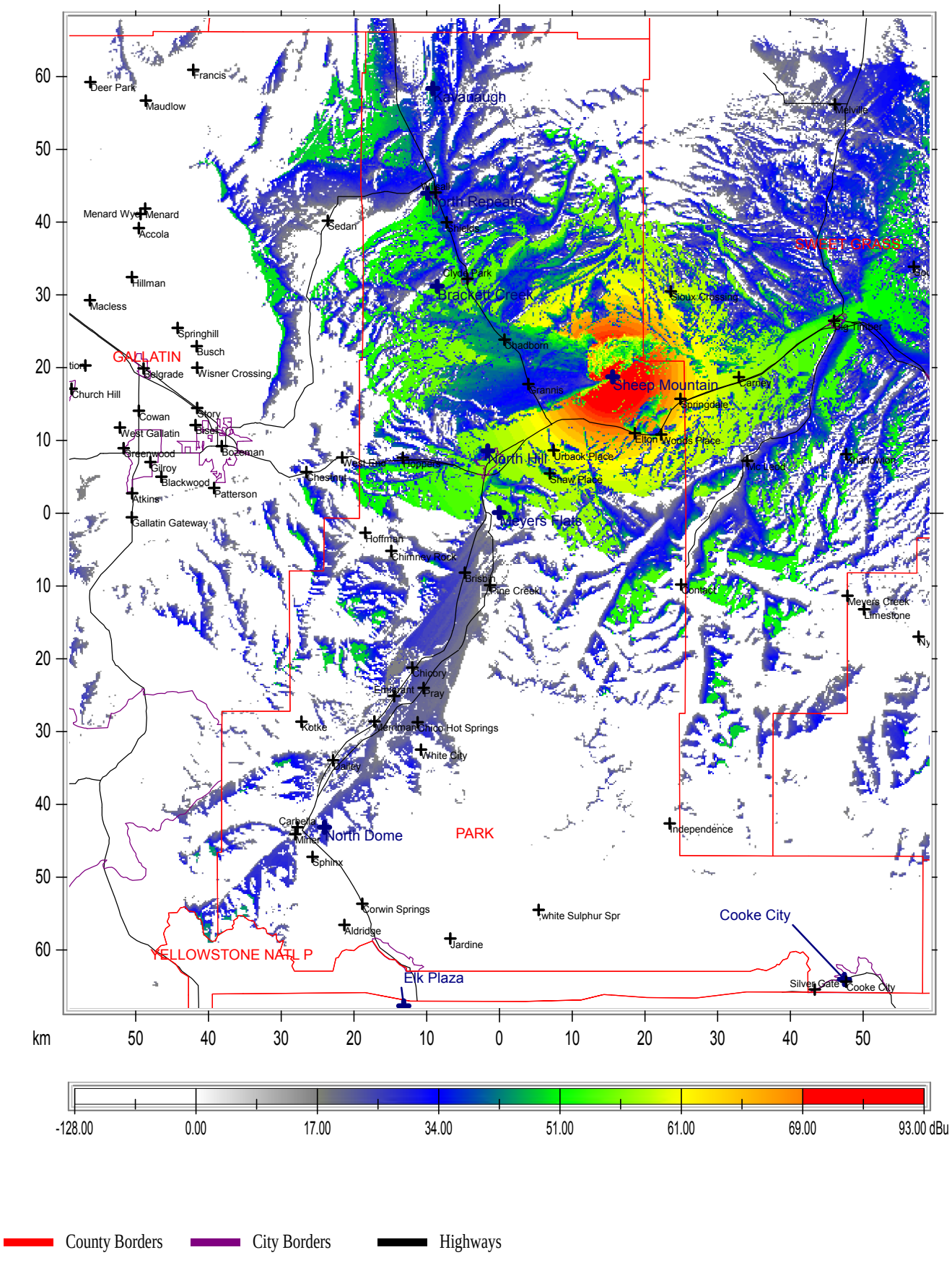

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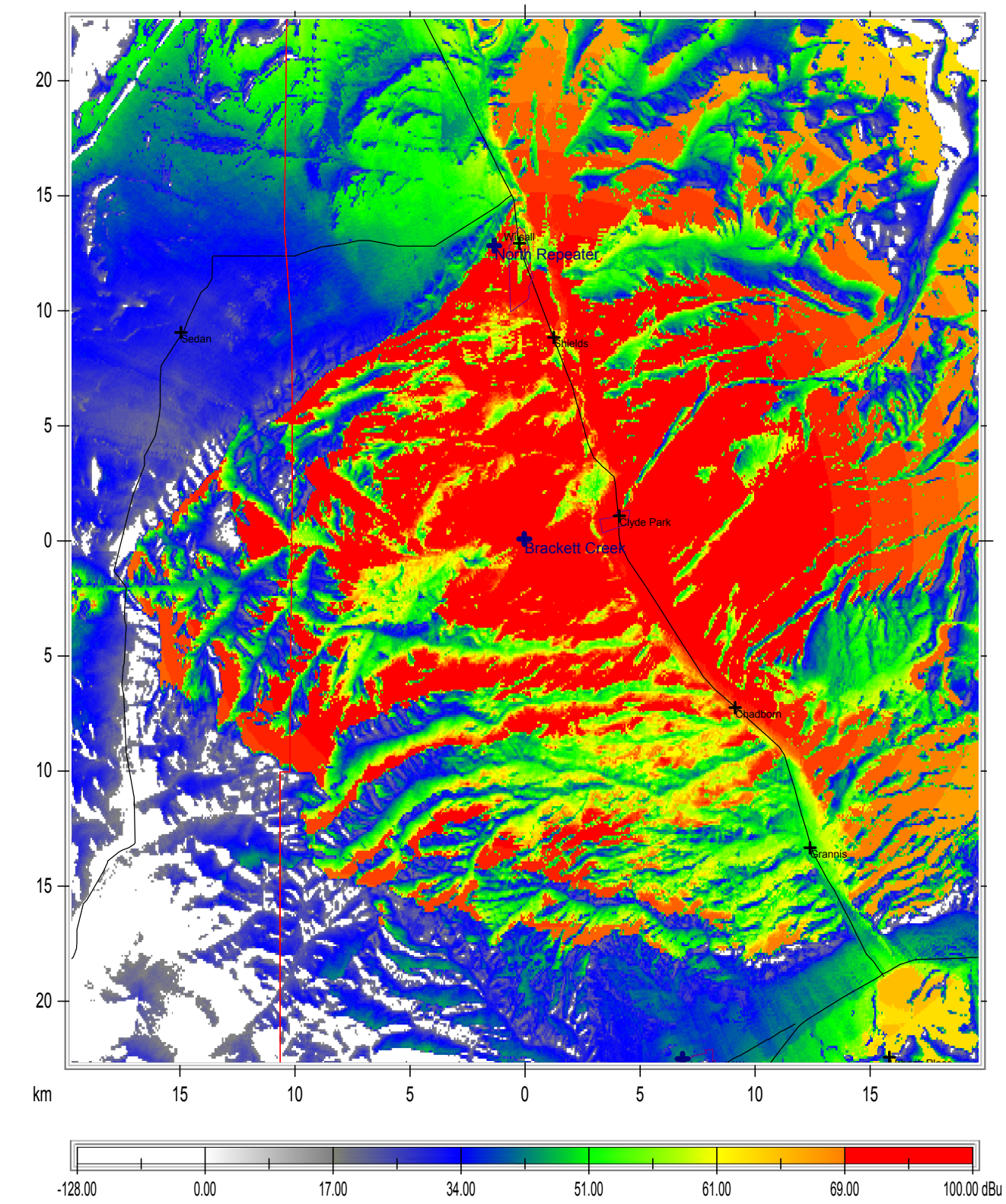
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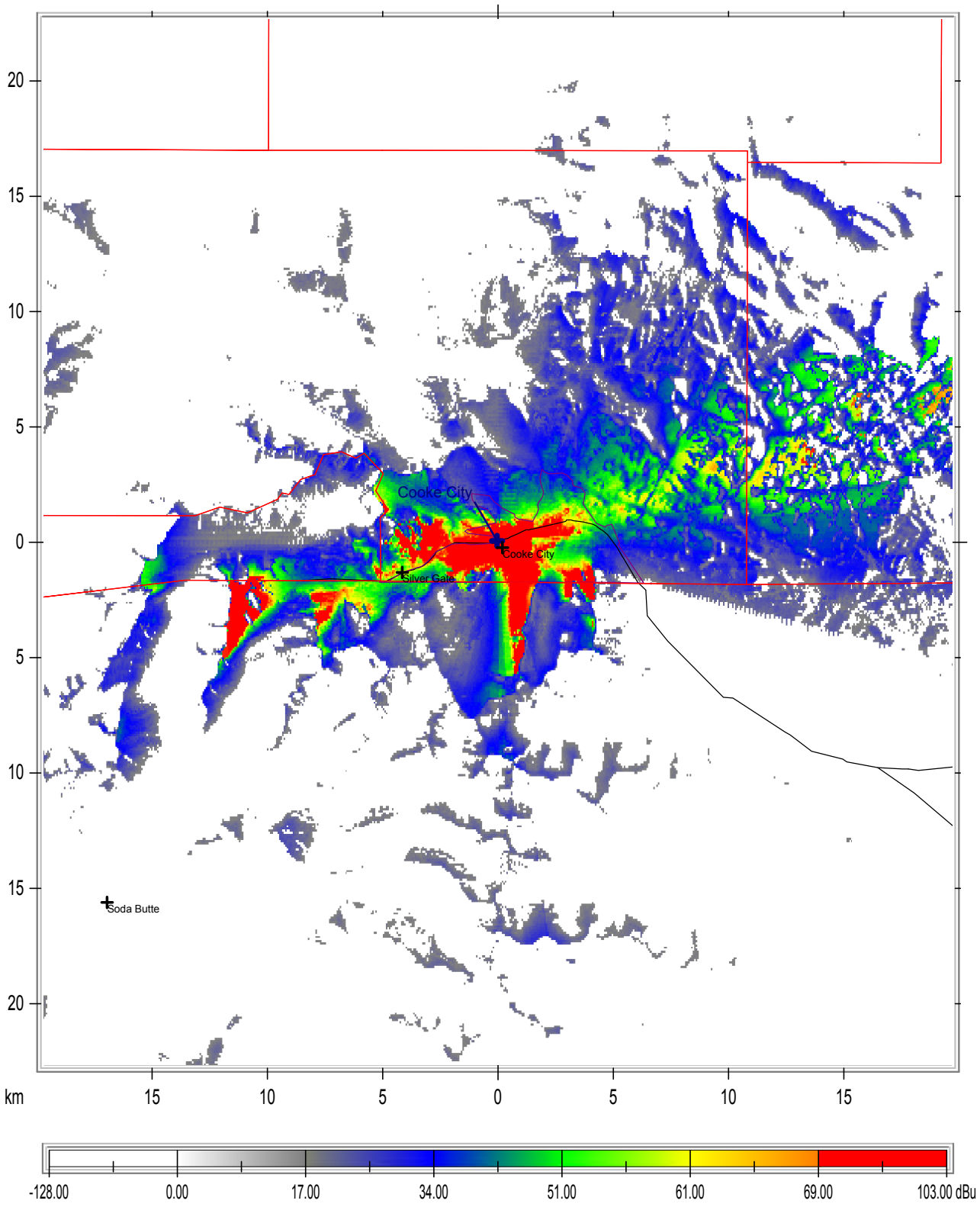
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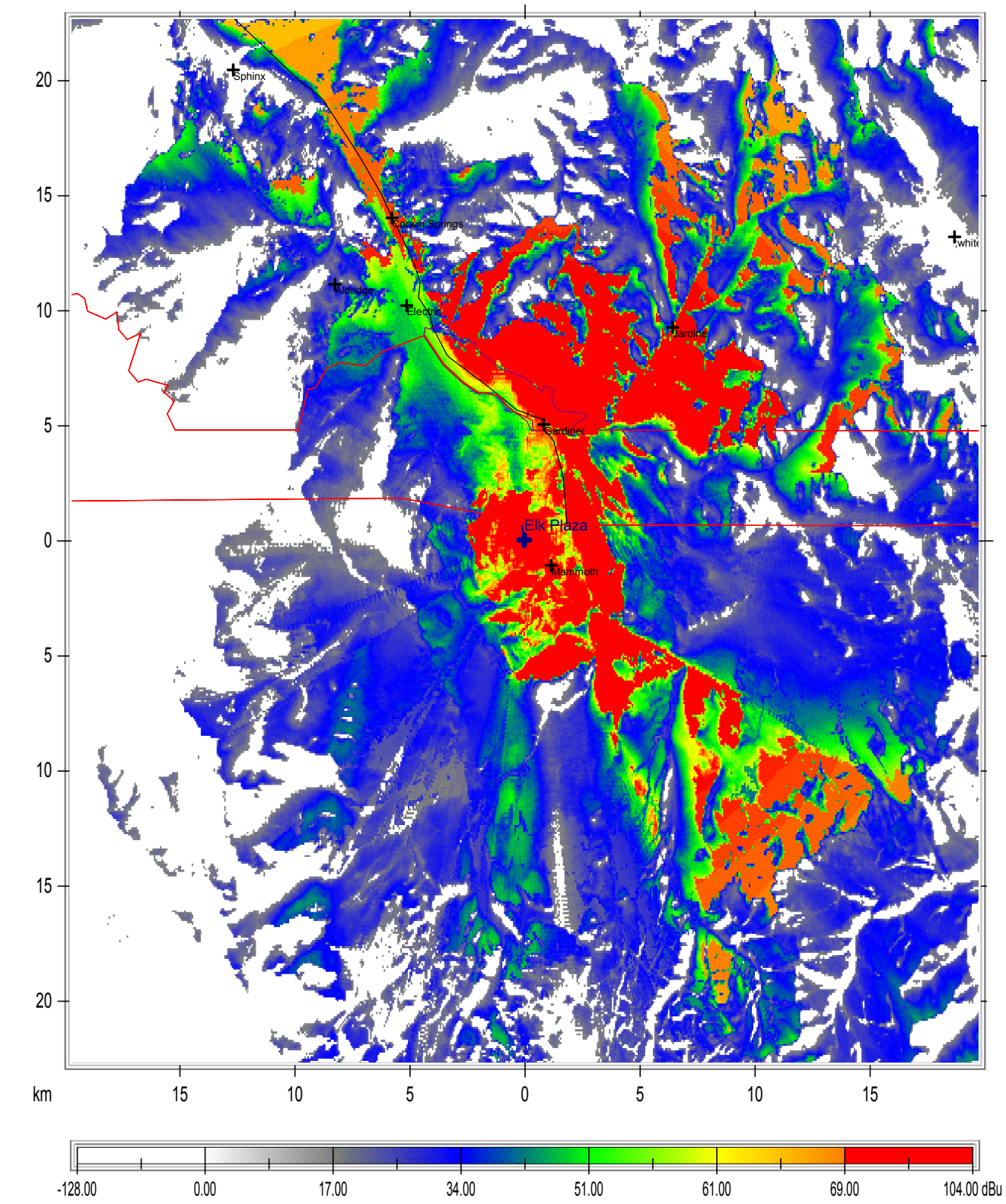
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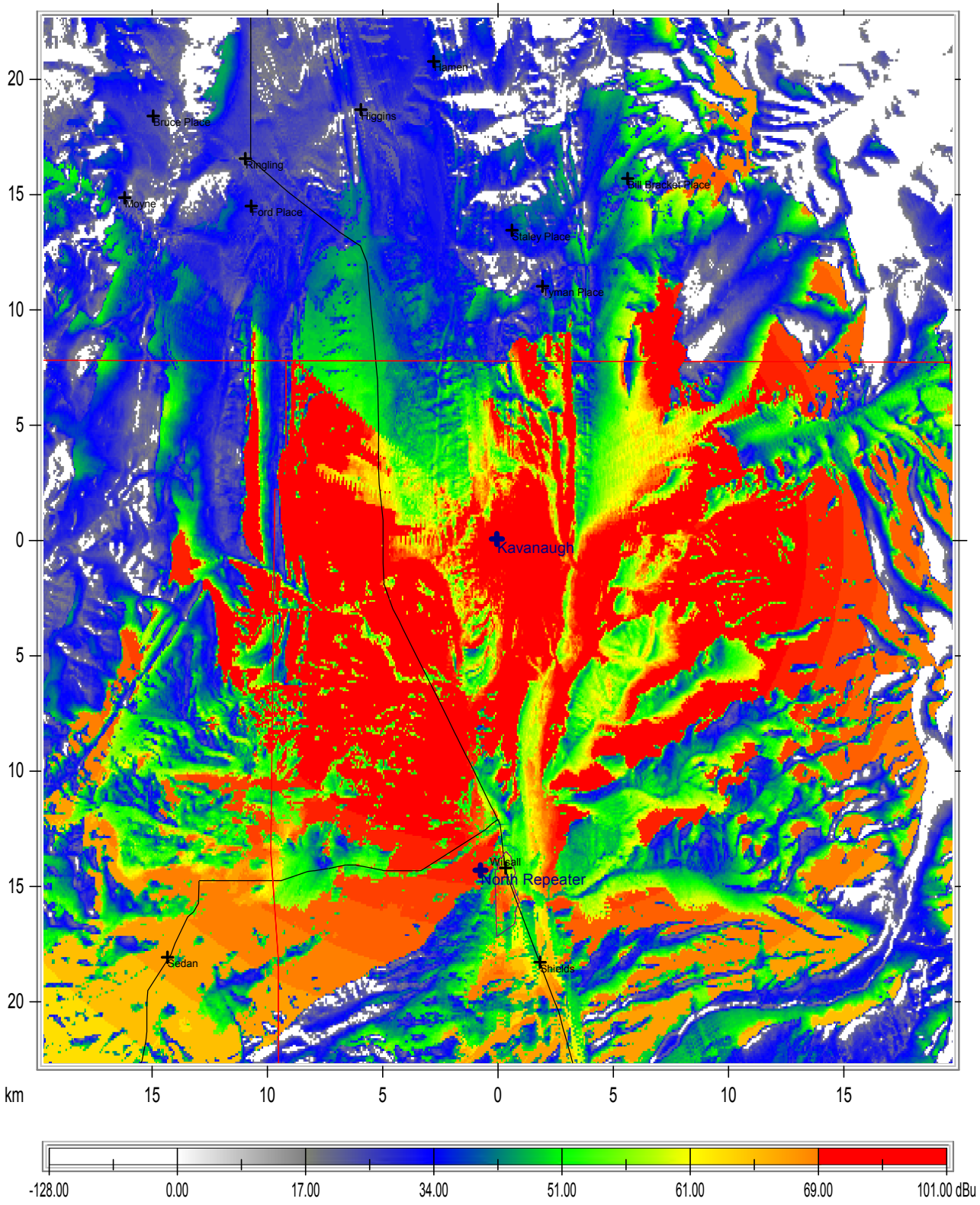
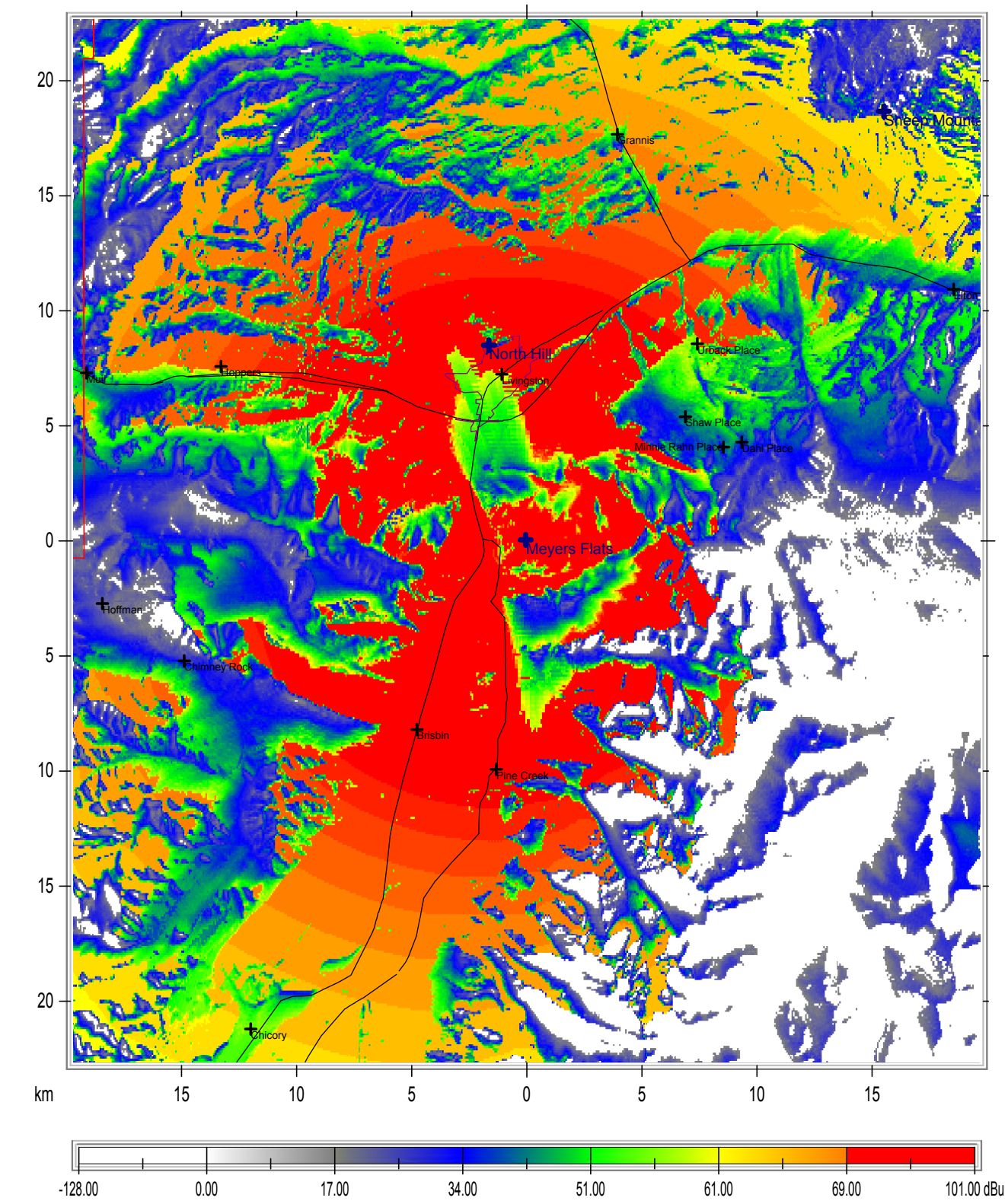


Map Scale: 1:250000 1 cm = 2.50 km V|H Size: 45.31 x 39.38 km


Sheep Mountain
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Meyers Flats
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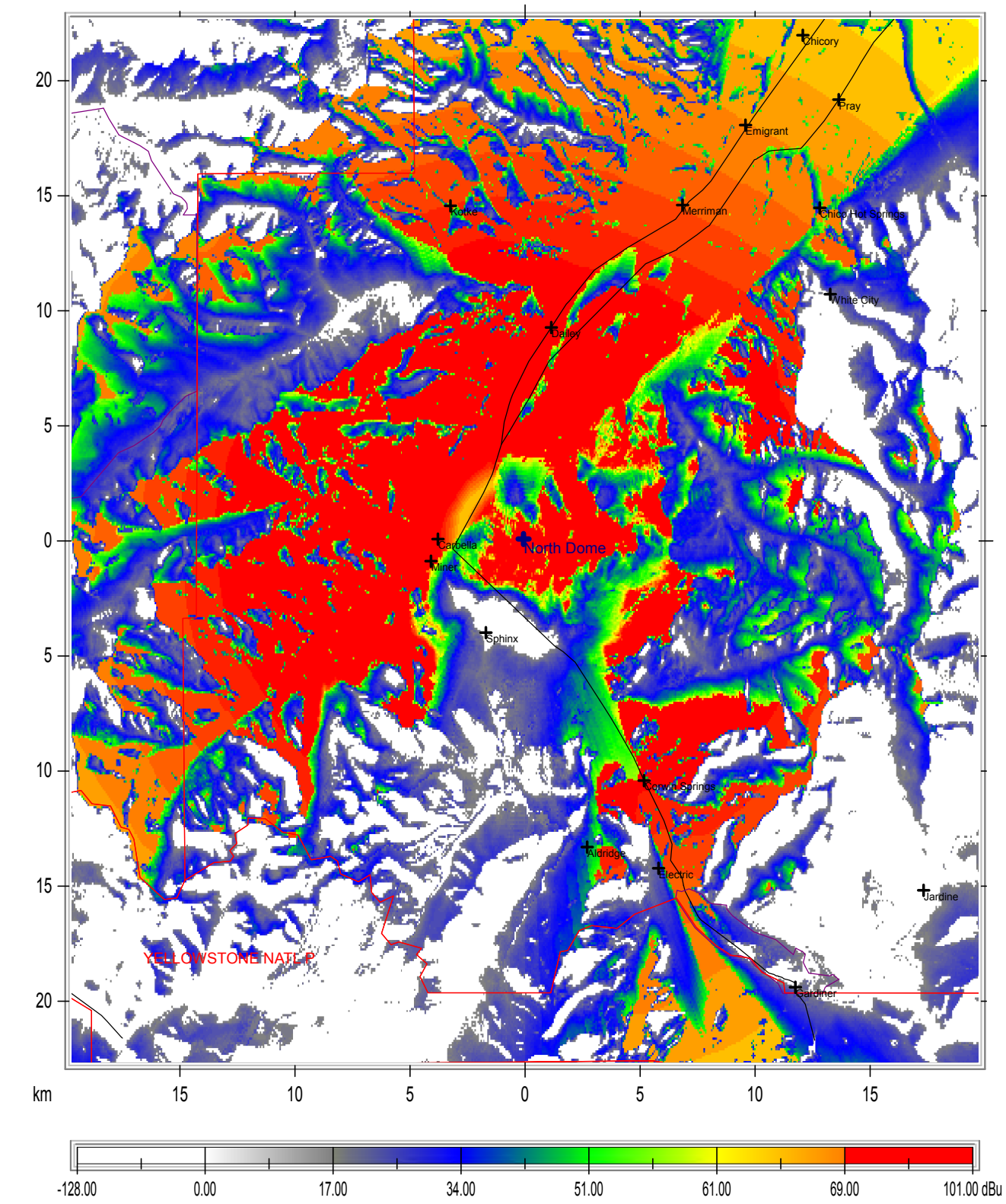
Chicory
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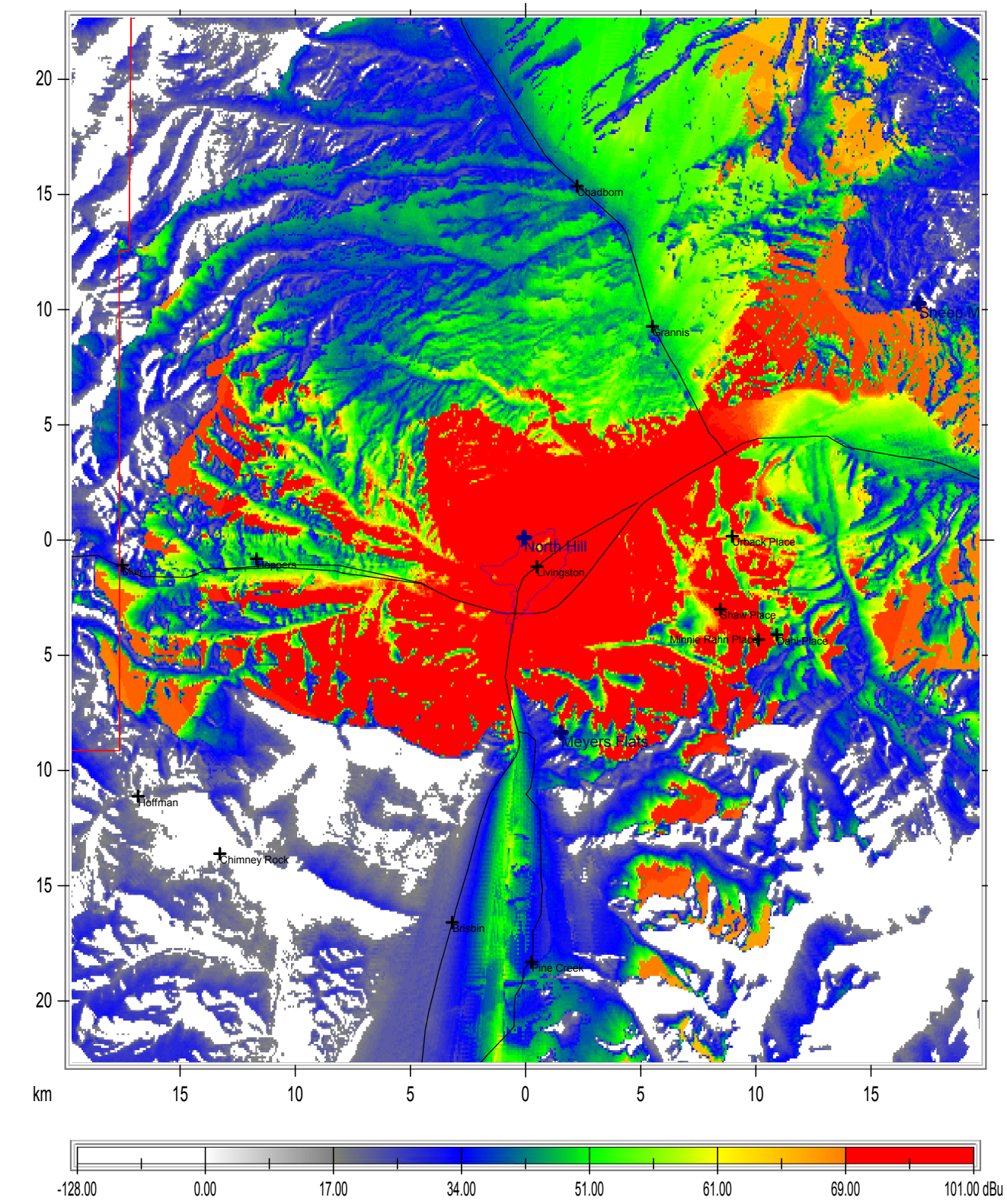
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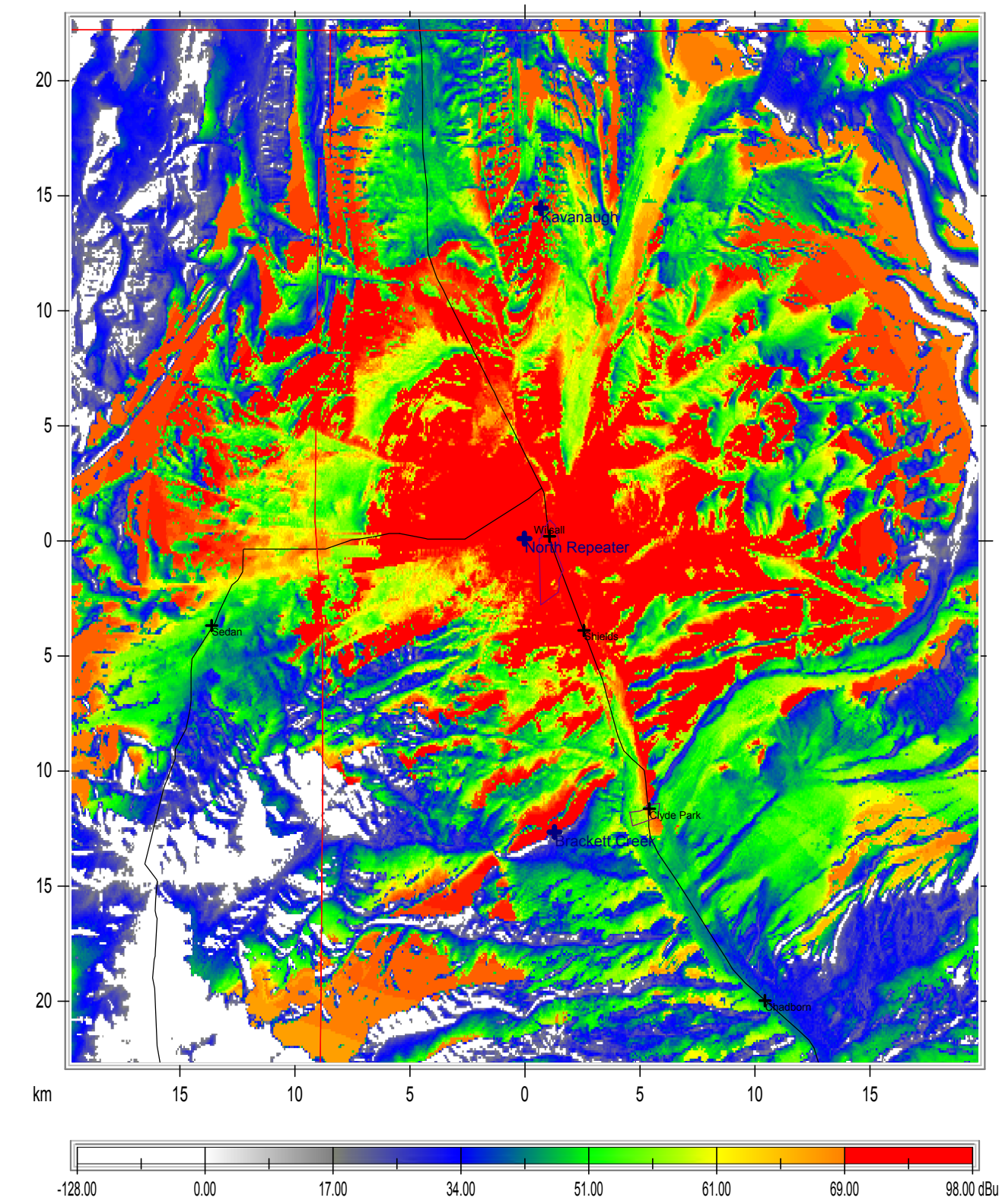
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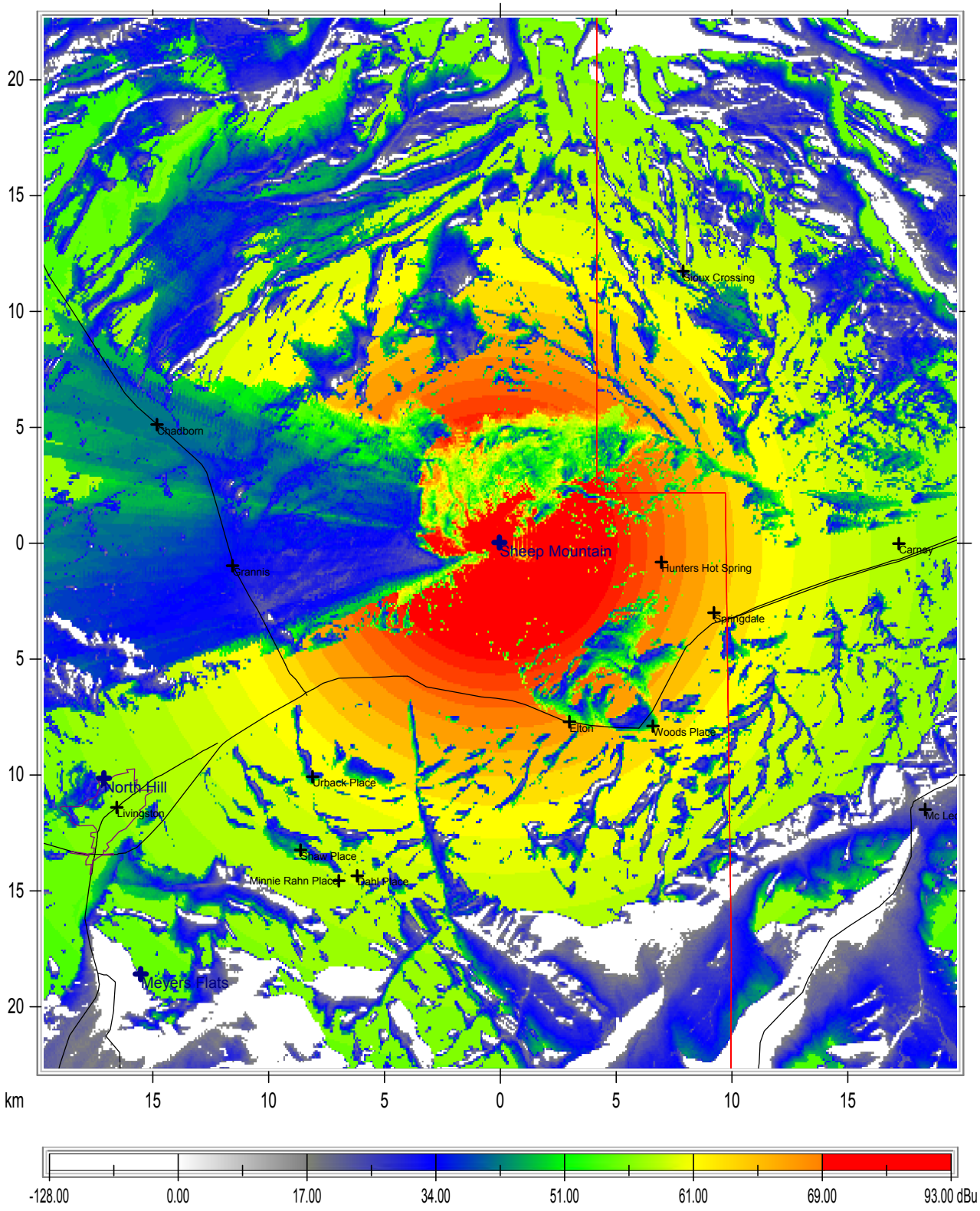
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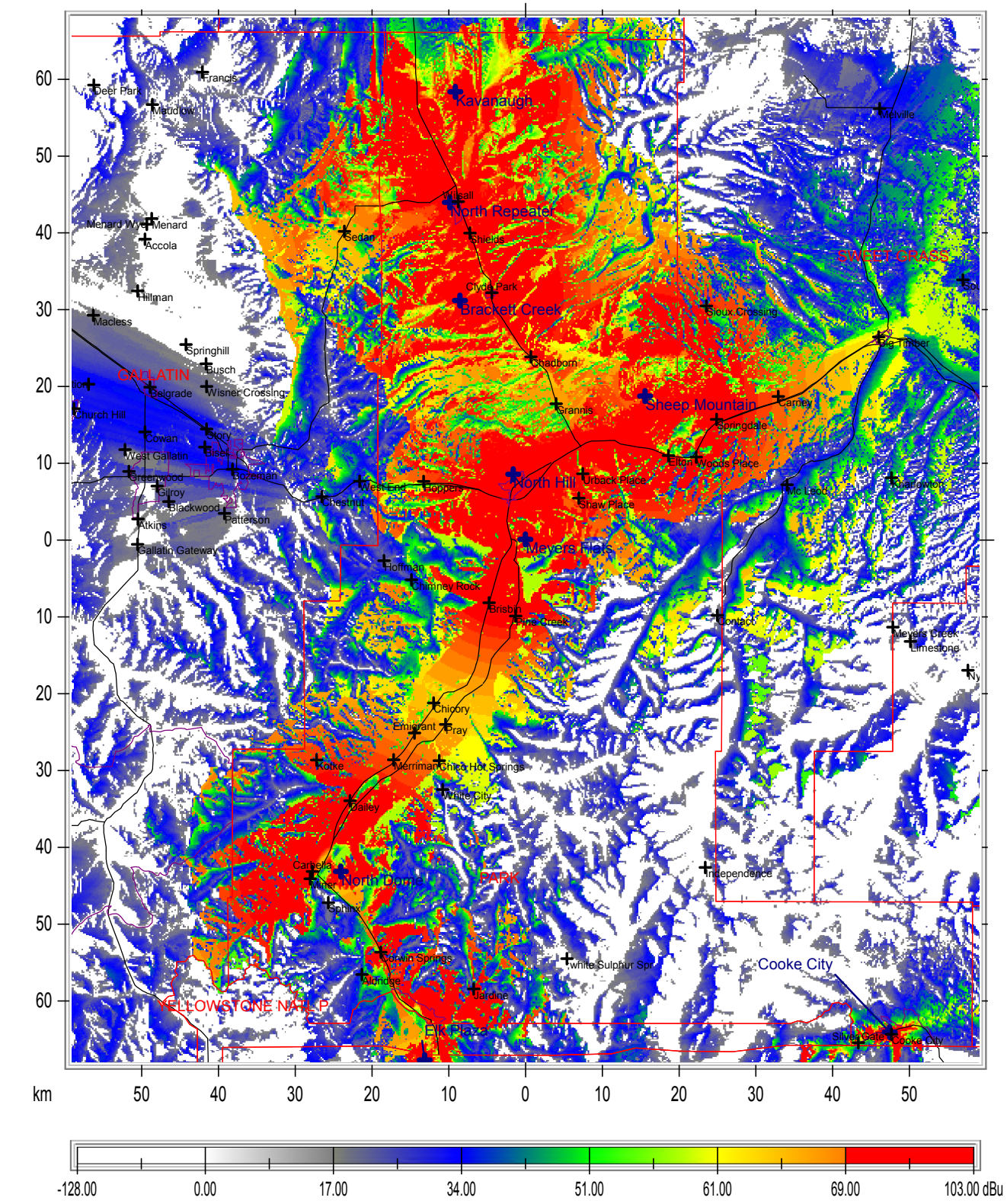
Deer Park
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Clyde Park
Brackett Creek
Sioux Crossing
Macless
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Wisner Crossing
Belgrade
Church Hill
Cowan
West Gallatin
Bisek
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Gilroy
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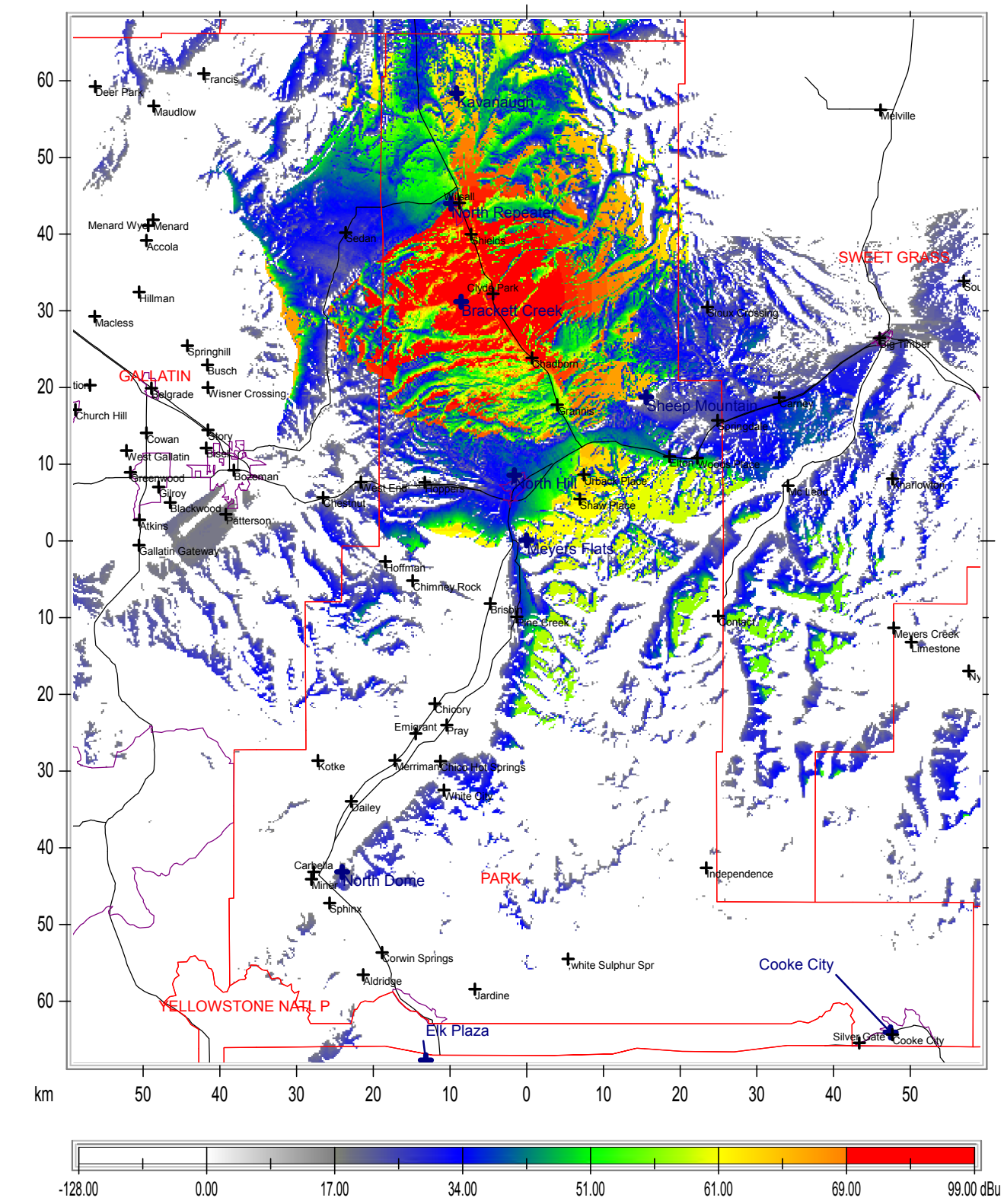
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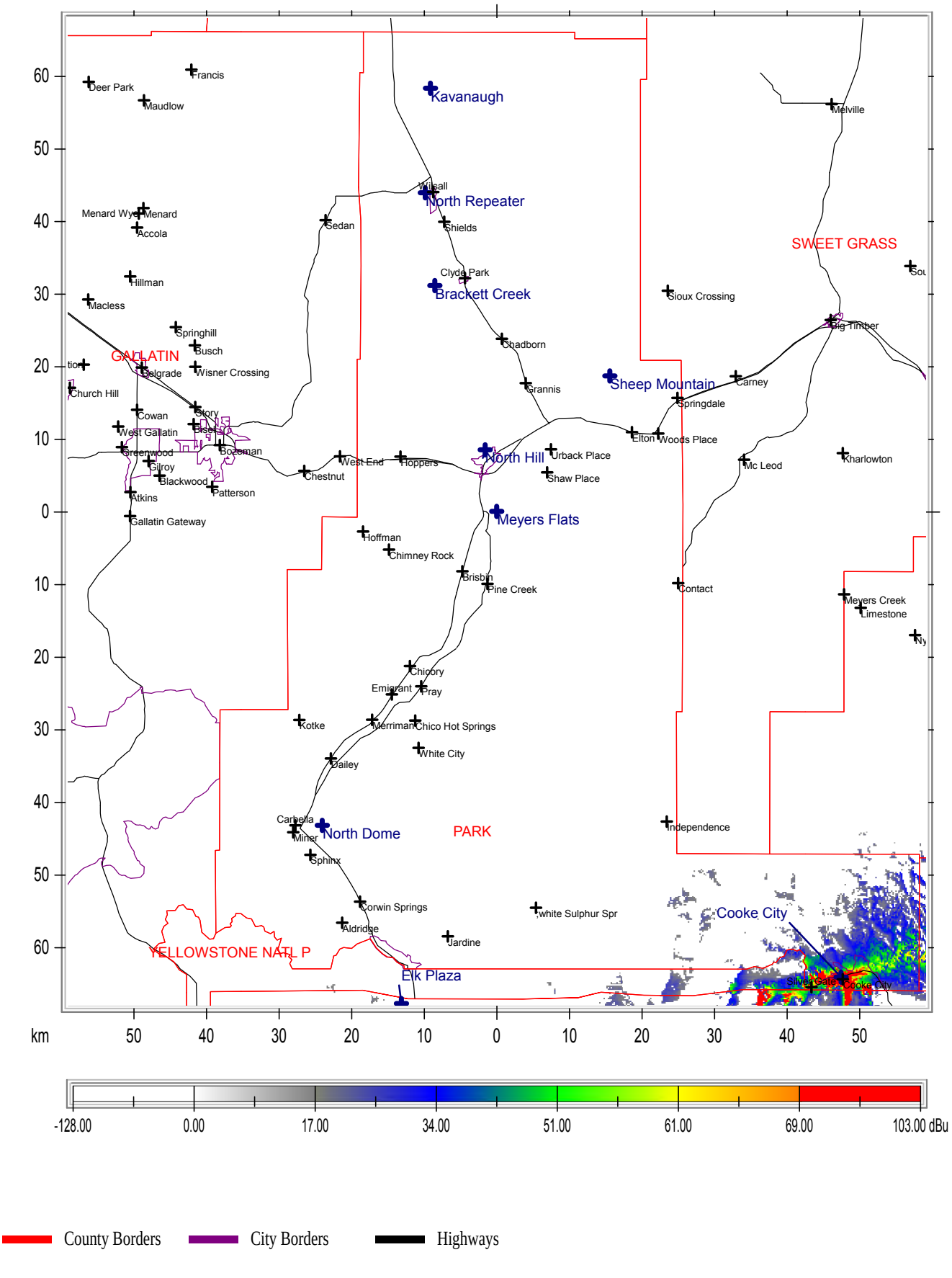
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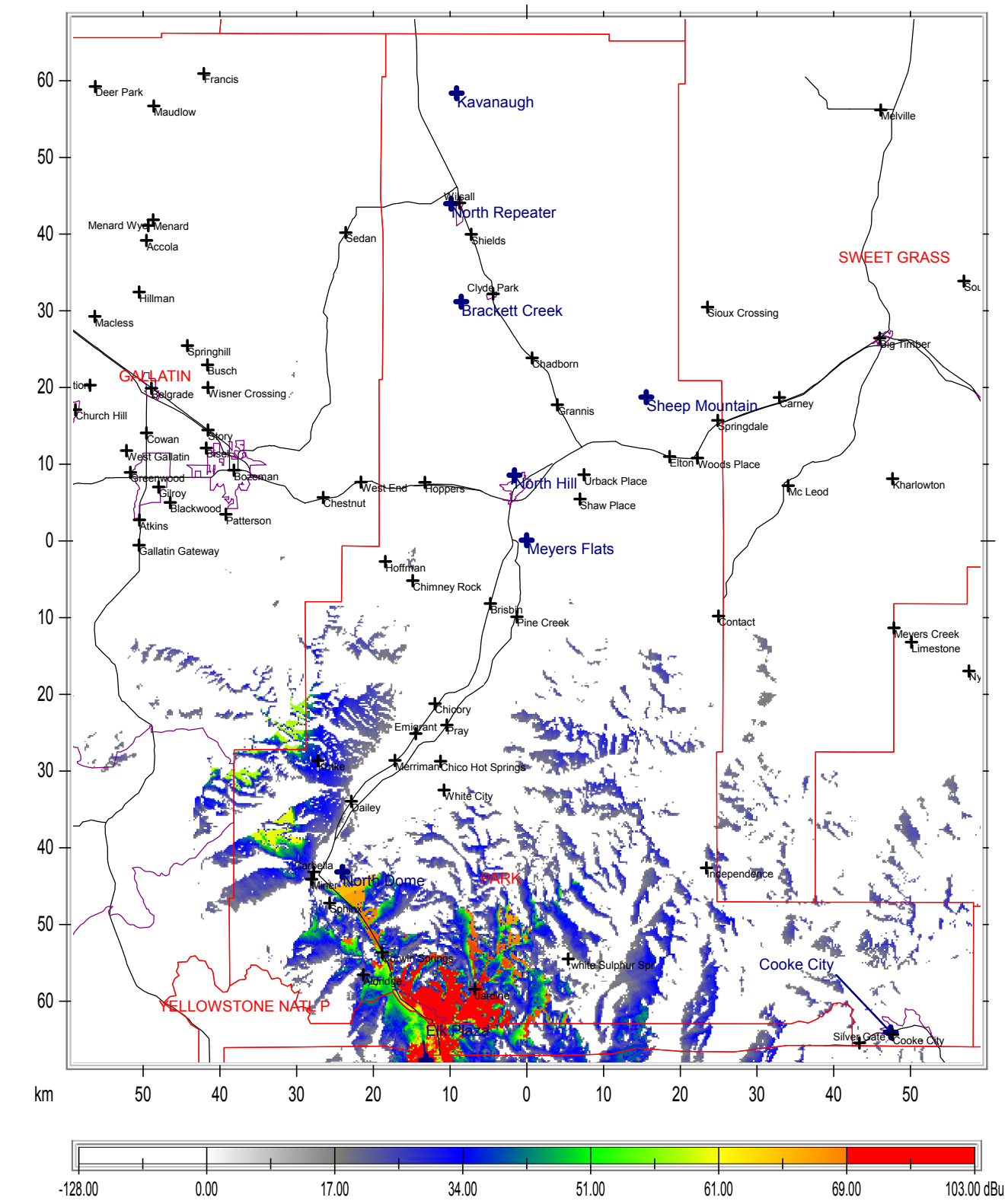
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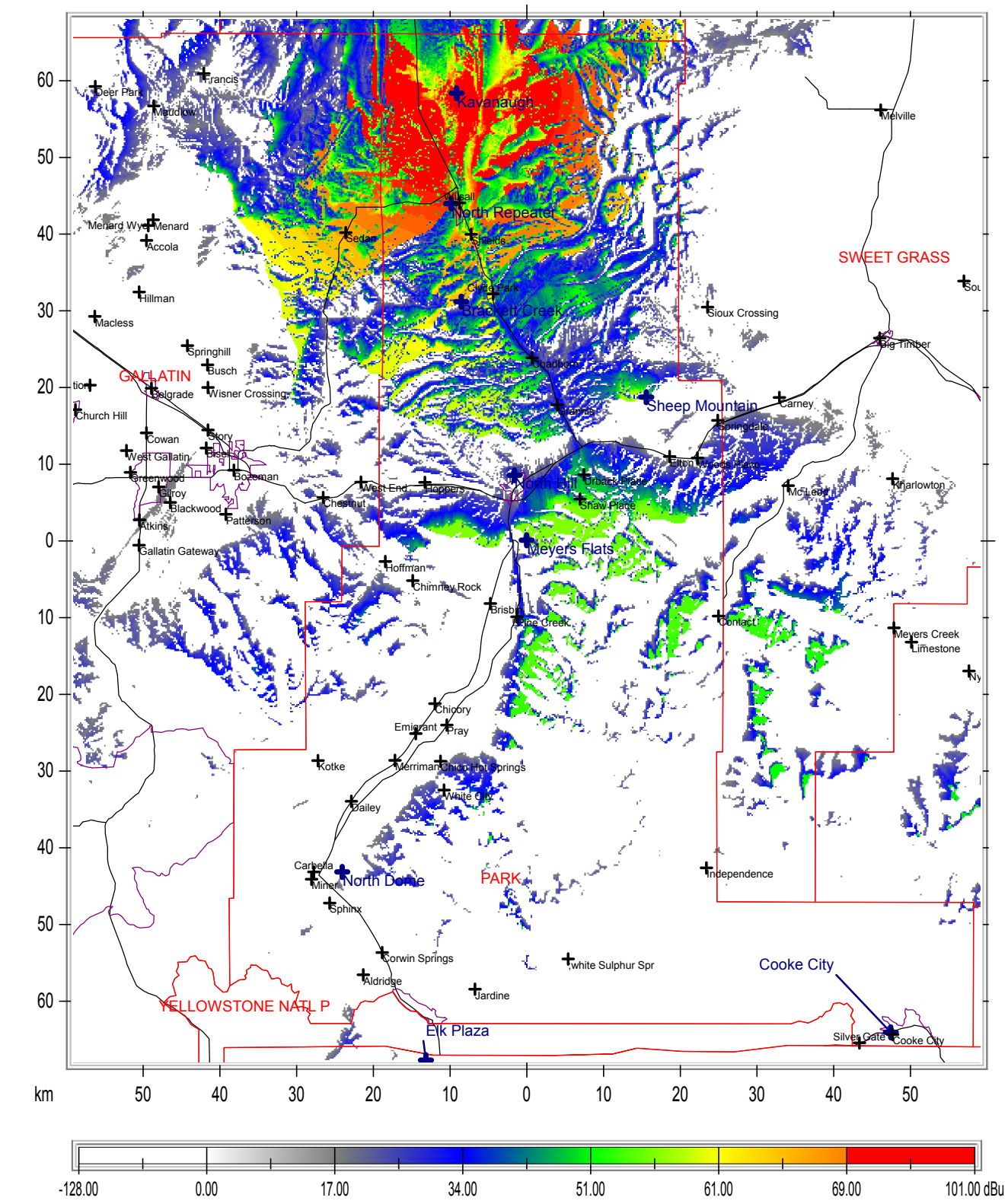
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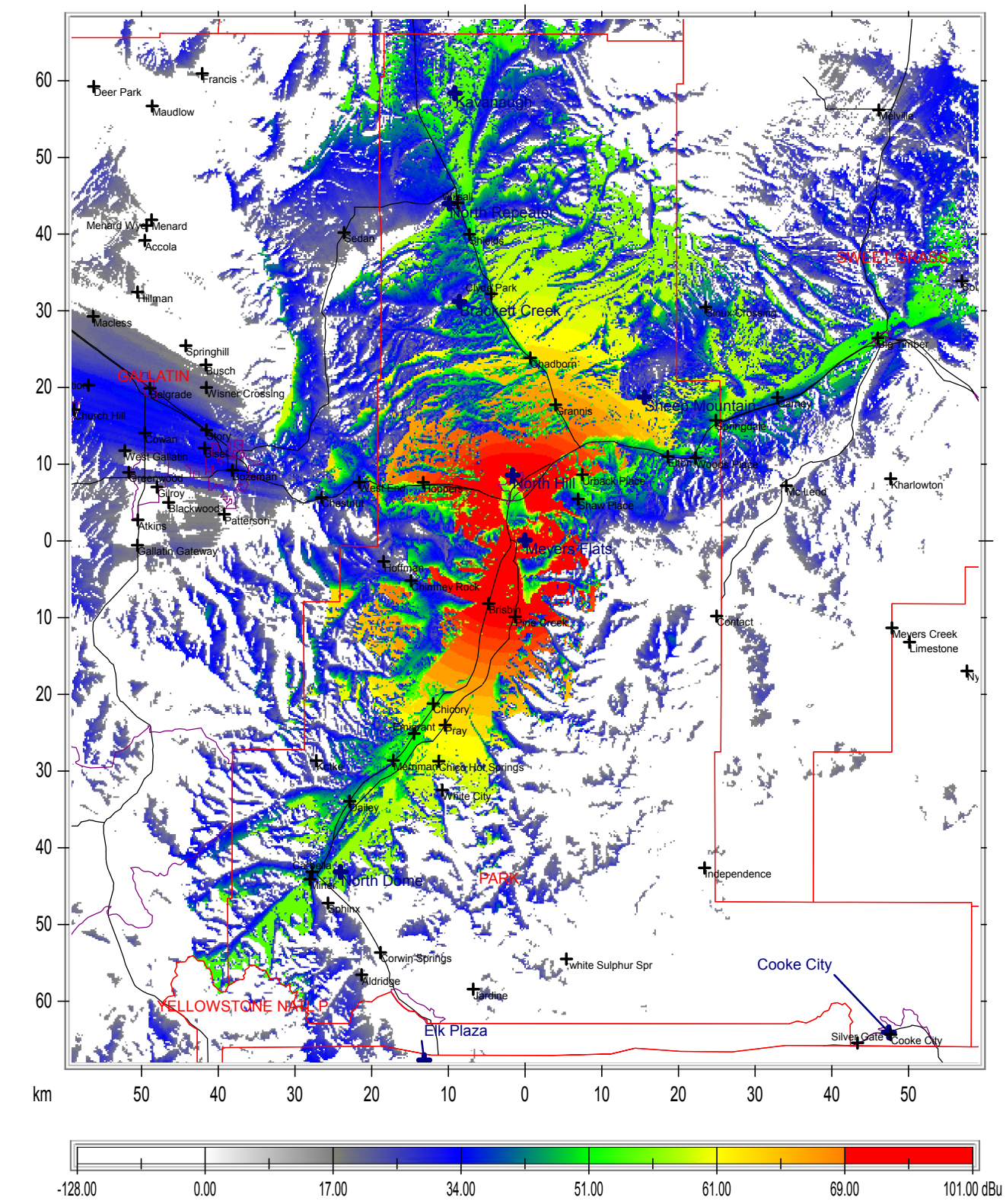
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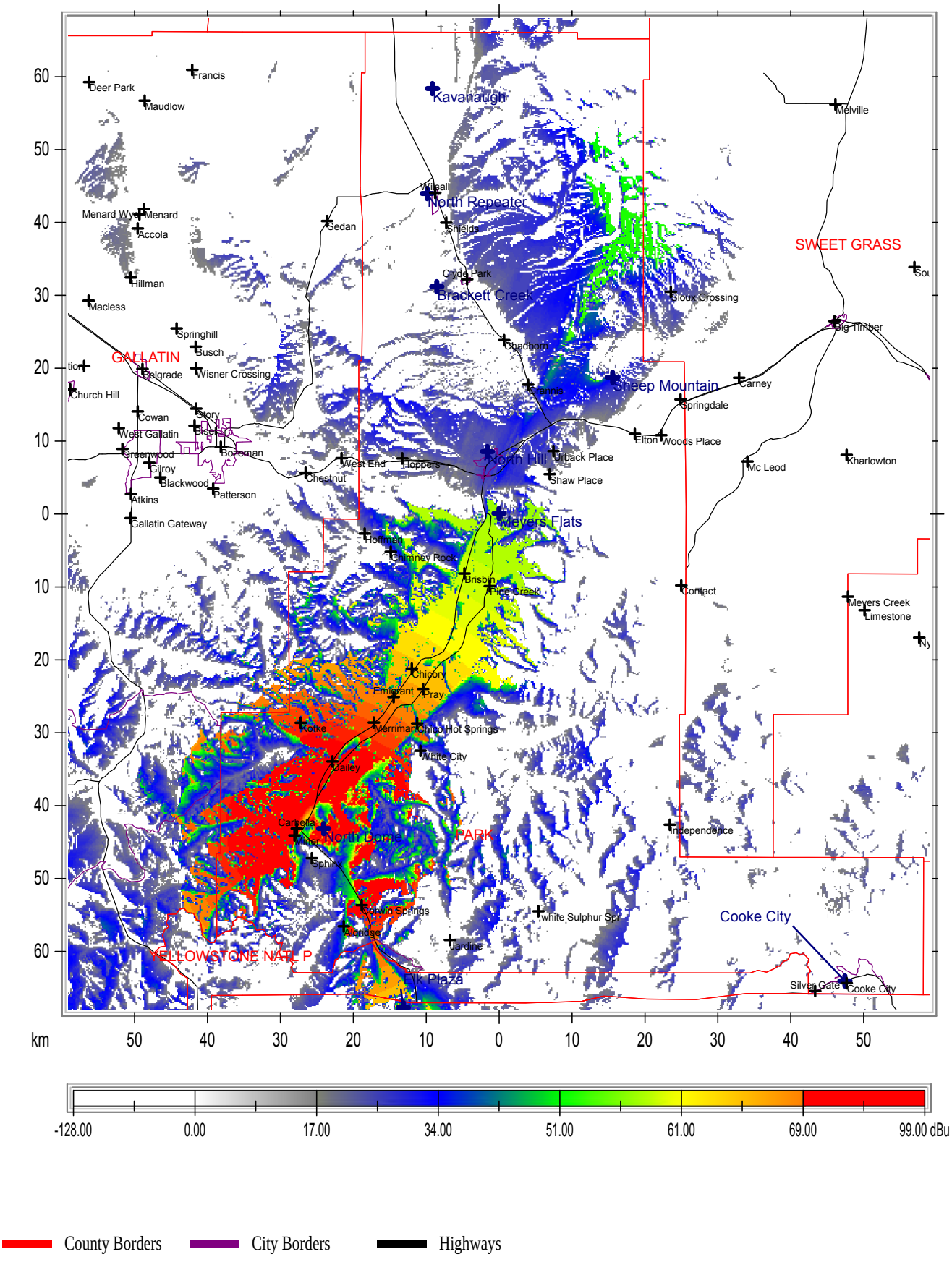
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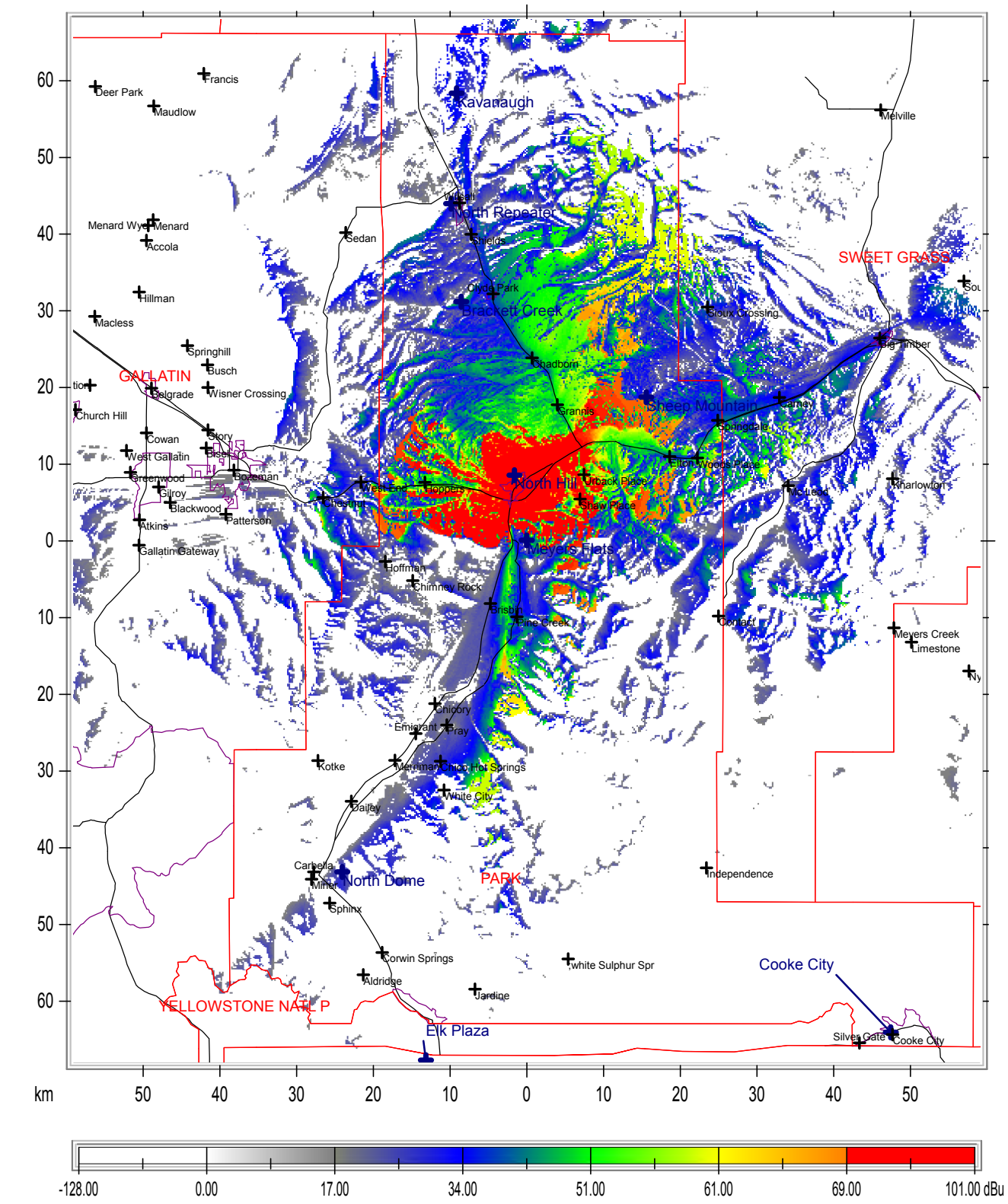
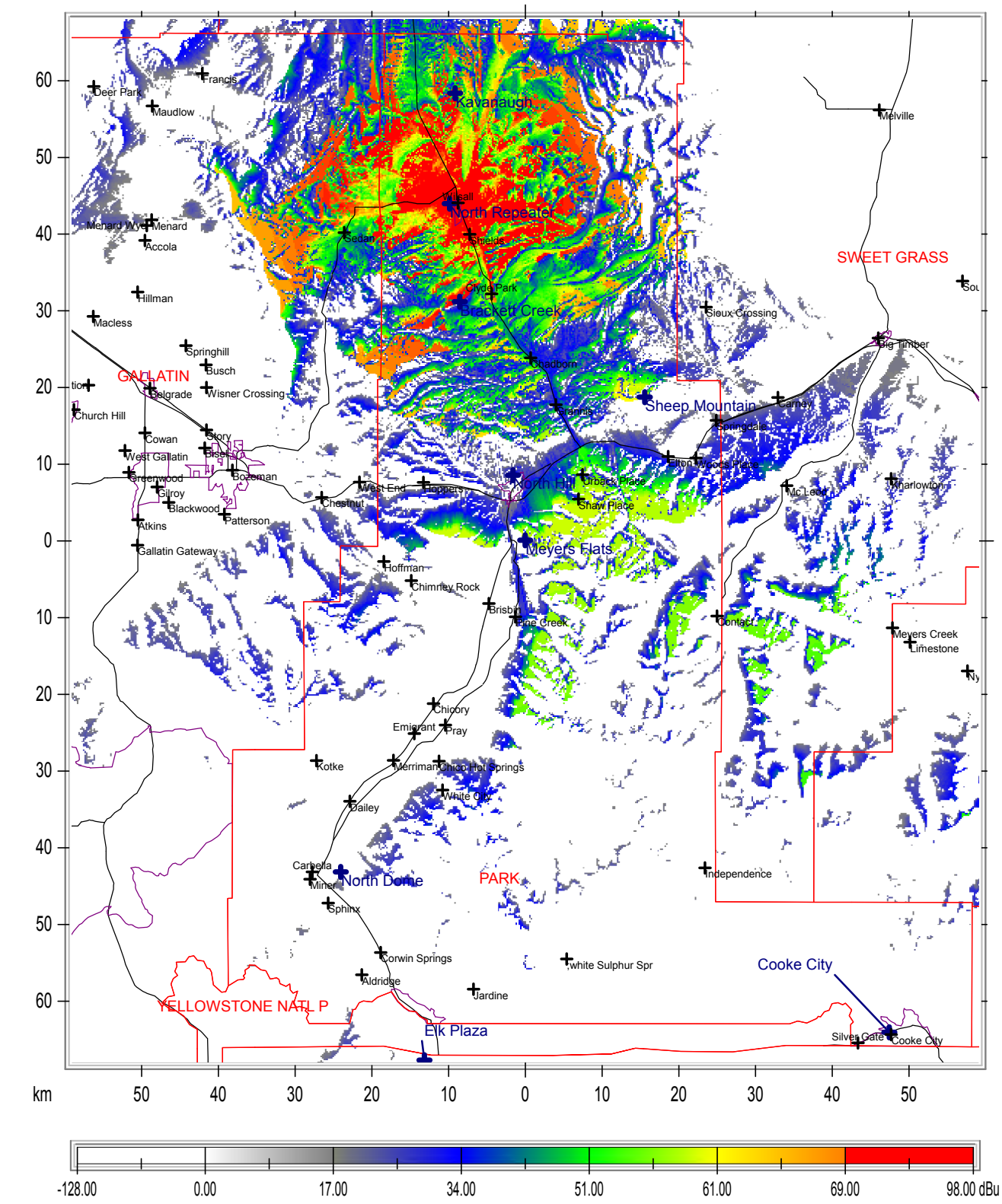
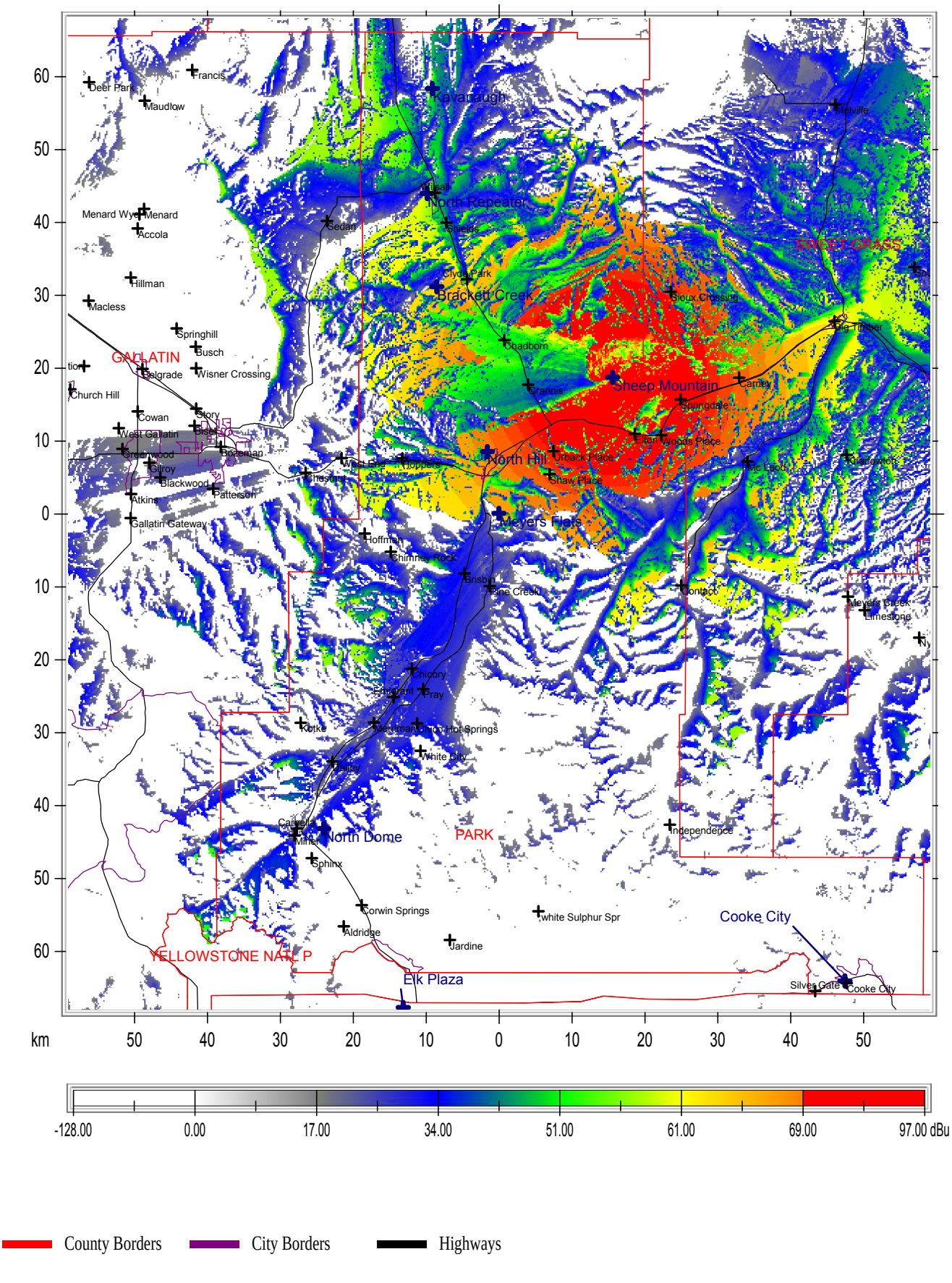


Map Scale: 1:750000 1 cm = 7.50 km V|H Size: 135.93 x 118.13 km



Map Scale: 1:750000 1 cm = 7.50 km V|H Size: 135.93 x 118.13 km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Appendix B
Radio Site Voice Frequencies and Tones

TABLE B-1
Radio Site Voice Frequencies and Tones

Radio Site	Channel Name / Operations	TX Frequency (MHz)	TX CTCSS Tone Frequency (Hz)	RX Frequency (MHz)	RX CTCSS Tone Frequency (Hz)
Meyers Flats	Law Repeater	155.5950	114.8	156.2100	146.2
Meyers Flats	Fire Repeater	154.4150	173.8	158.8350	167.9
Meyers Flats	Park County SO Repeater	154.860	179.9	155.3700	162.2
Meyers Flats	Park County Roads Repeater	151.0775	114.8	156.1050	123.0
North	Fire Repeater	154.4150	114.8	158.8350	114.8
North Hill	Direct Fire Base & Control Station #1	154.4150	173.8	154.4150	173.8
North Hill	South Base & Control Station #1	158.9625	118.8	154.1900	118.8
North Hill	North Repeater Base & Control Station #1	158.8350	114.8	154.4150	114.8
North Hill	Gold Base & Control Station #2	153.9050	156.7	153.9050	CSQ[28]
North Hill	Direct Law Base & Control Station #2	155.5950	114.8	155.5950	114.8
North Hill	Direct Fire Base & Control Station #2	154.4150	CSQ	154.4150	CSQ
North Hill	Direct PCSO Base & Control Station #2	154.8600	162.2	154.8600	179.9
North Hill	Wilsall Mountain Base & Control Station #2	158.8350	114.8	154.4150	114.8
North Hill	City Fire Base & Control Station #2	154.3400	114.8	154.3400	114.8
North Hill	Ruby Garnet Base & Control Station #2	159.3450	114.8	153.8300	114.8

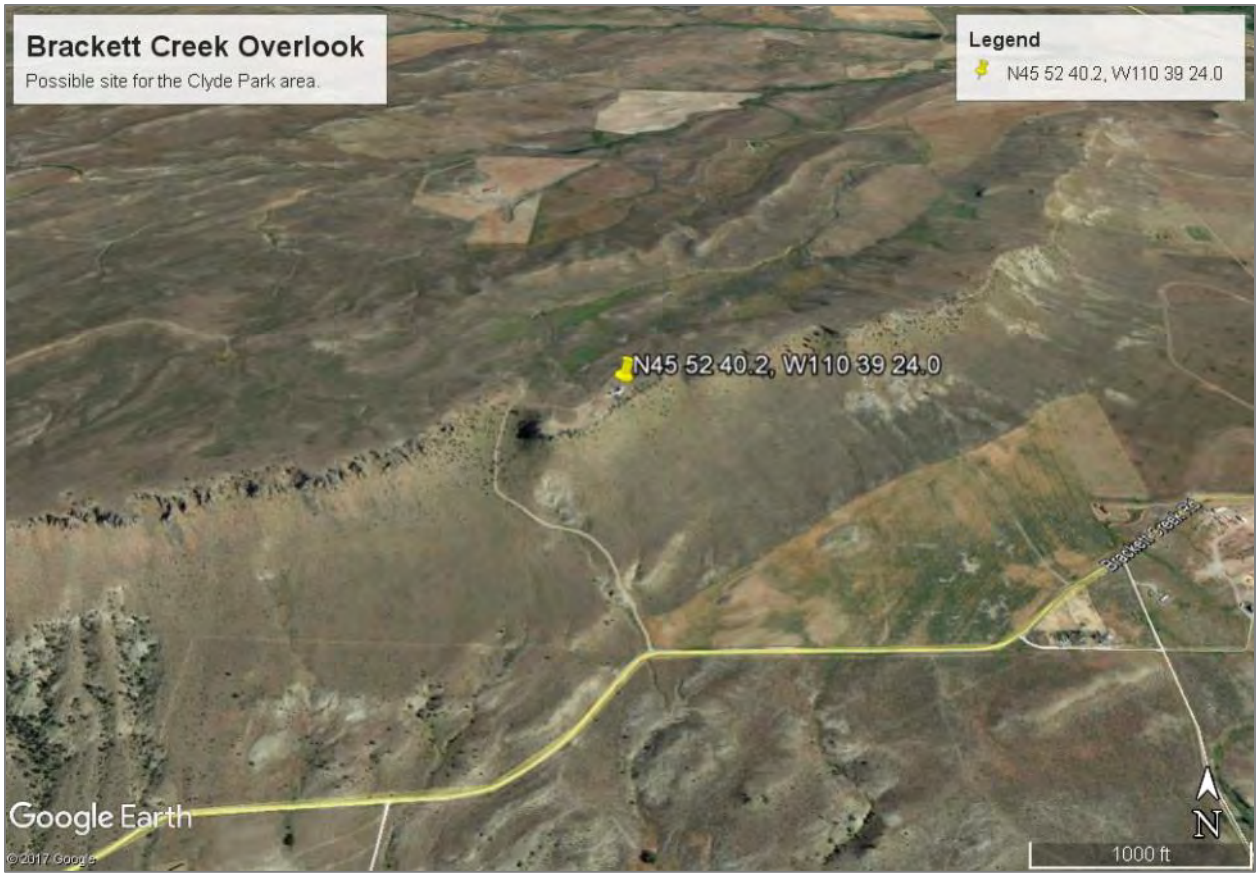
[28] CSQ is commonly known as carrier squelch. Any signal with or without a subaudible tone is heard on the receiver.

TABLE B-1 (continued)
Radio Site Voice Frequencies and Tones

Radio Site	Channel Name / Operations	TX Frequency (MHz)	TX CTCSS Tone Frequency (Hz)	RX Frequency (MHz)	RX CTCSS Tone Frequency (Hz)
North Hill	PTAC 1 Base & Control Station #2	153.8750	114.8	153.8750	114.8
North Hill	PTAC 2 Base & Control Station #2	154.1150	114.8	154.1150	114.8
North Hill	PTAC 3 Base & Control Station #2	156.1650	114.8	156.1650	114.8

Appendix C
Site Photographs

Bracket Creek



Photograph BC-1

Cooke City

Photograph CC-1

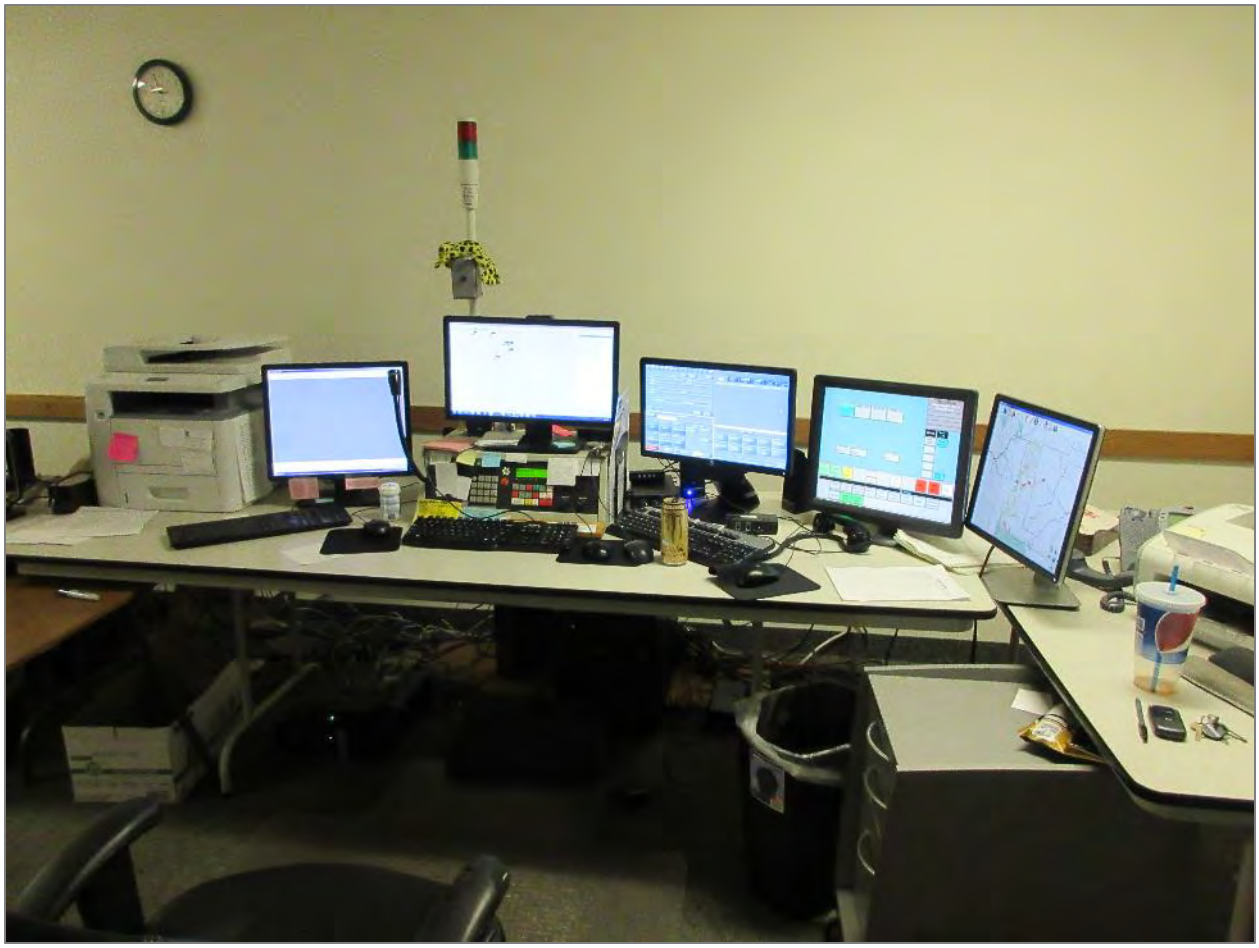
Elk Plaza

Photograph EP-1

Kavanaugh

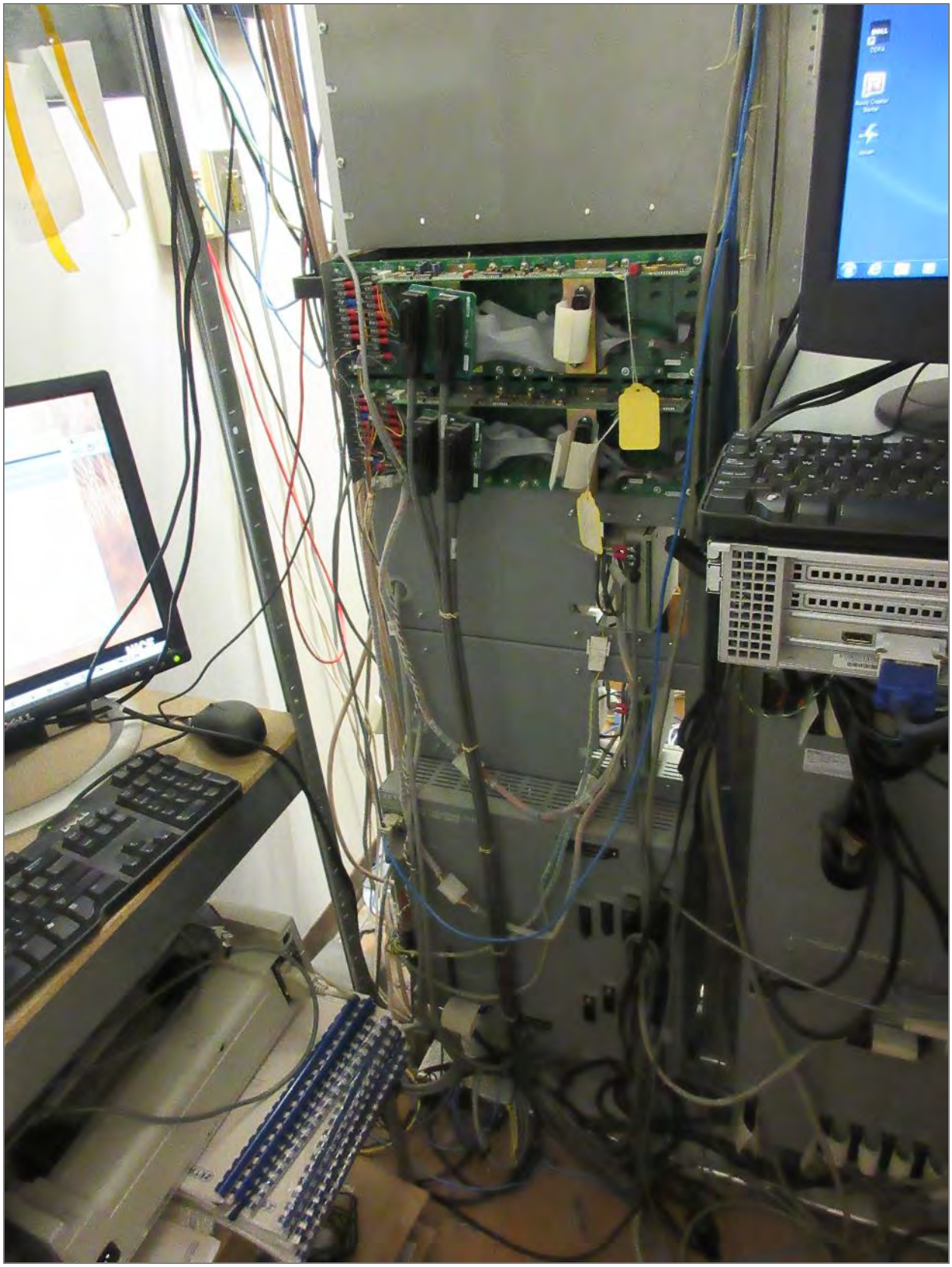
Photograph K-1

Livingston 9-1-1 Center

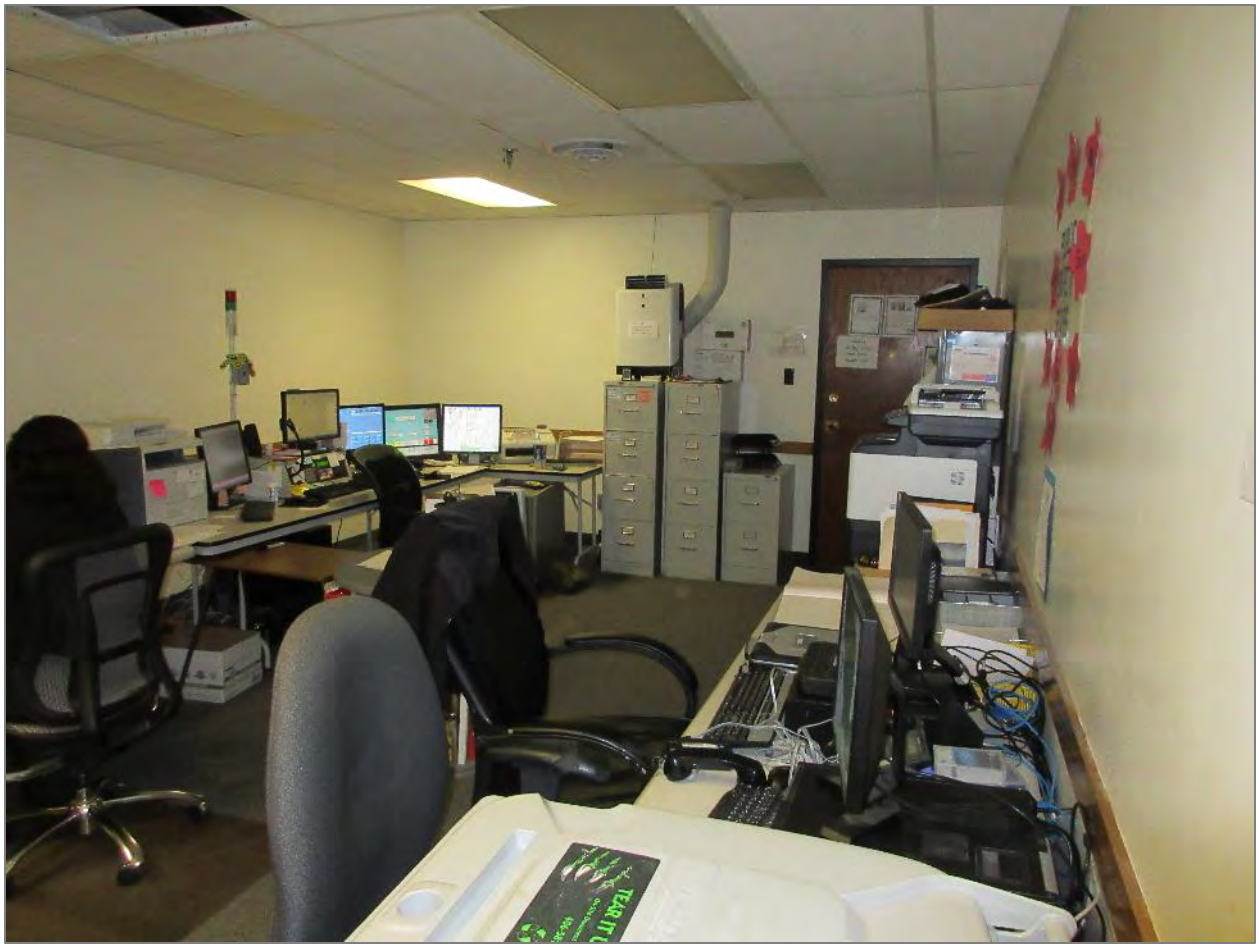


Photograph L911-1

Photograph L911-2



Photograph L911-3



Photograph L911-4

Meyers Flats

Photograph MF-1

Photograph MF-2

Photograph MF-3

Photograph MF-4

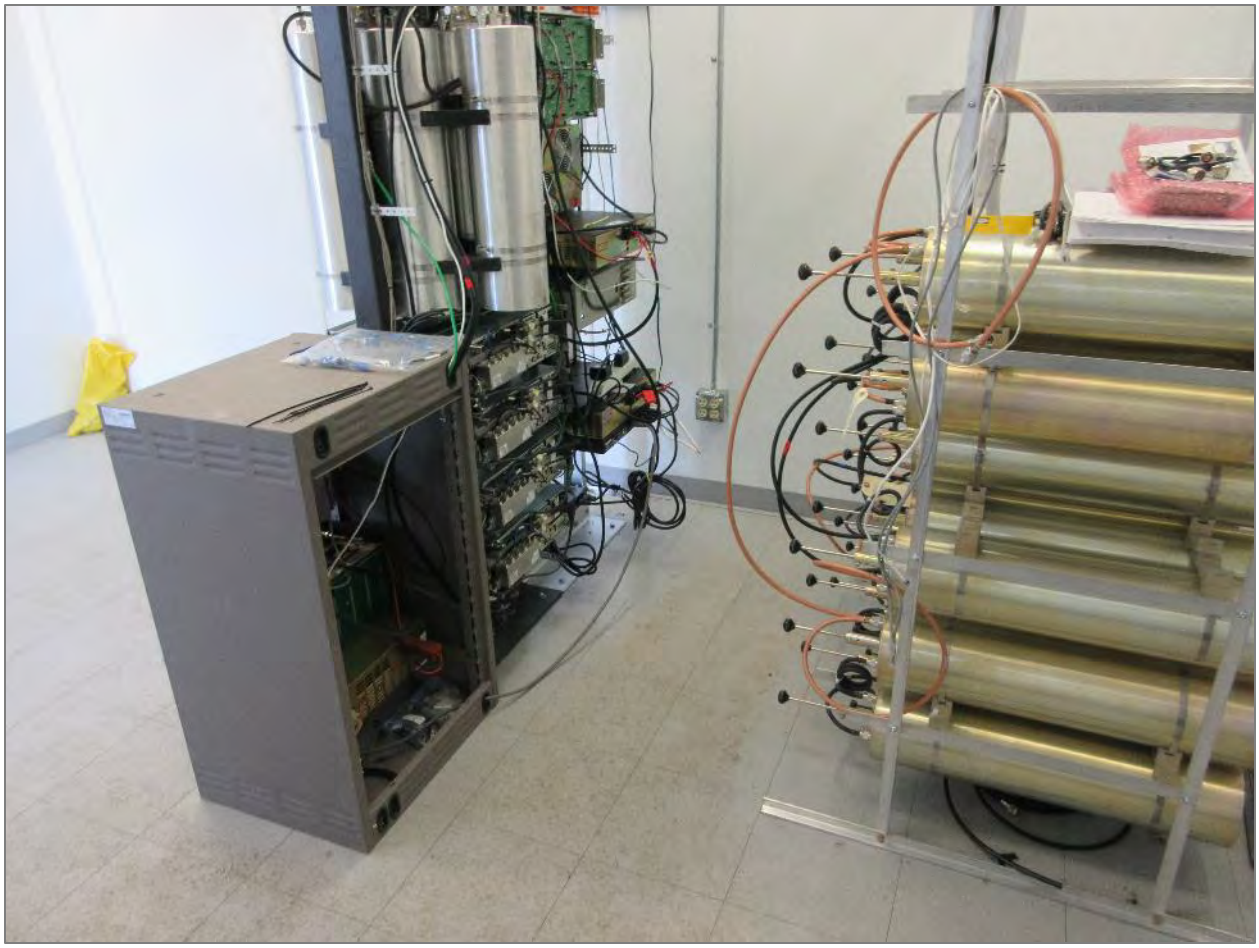
Photograph MF-5

Photograph MF-6

Photograph MF-7

Photograph MF-8

Photograph MF-9



Photograph MF-10

Photograph MF-11

North Fire

Photograph N-1A

Photograph N-1B

Photograph N-2

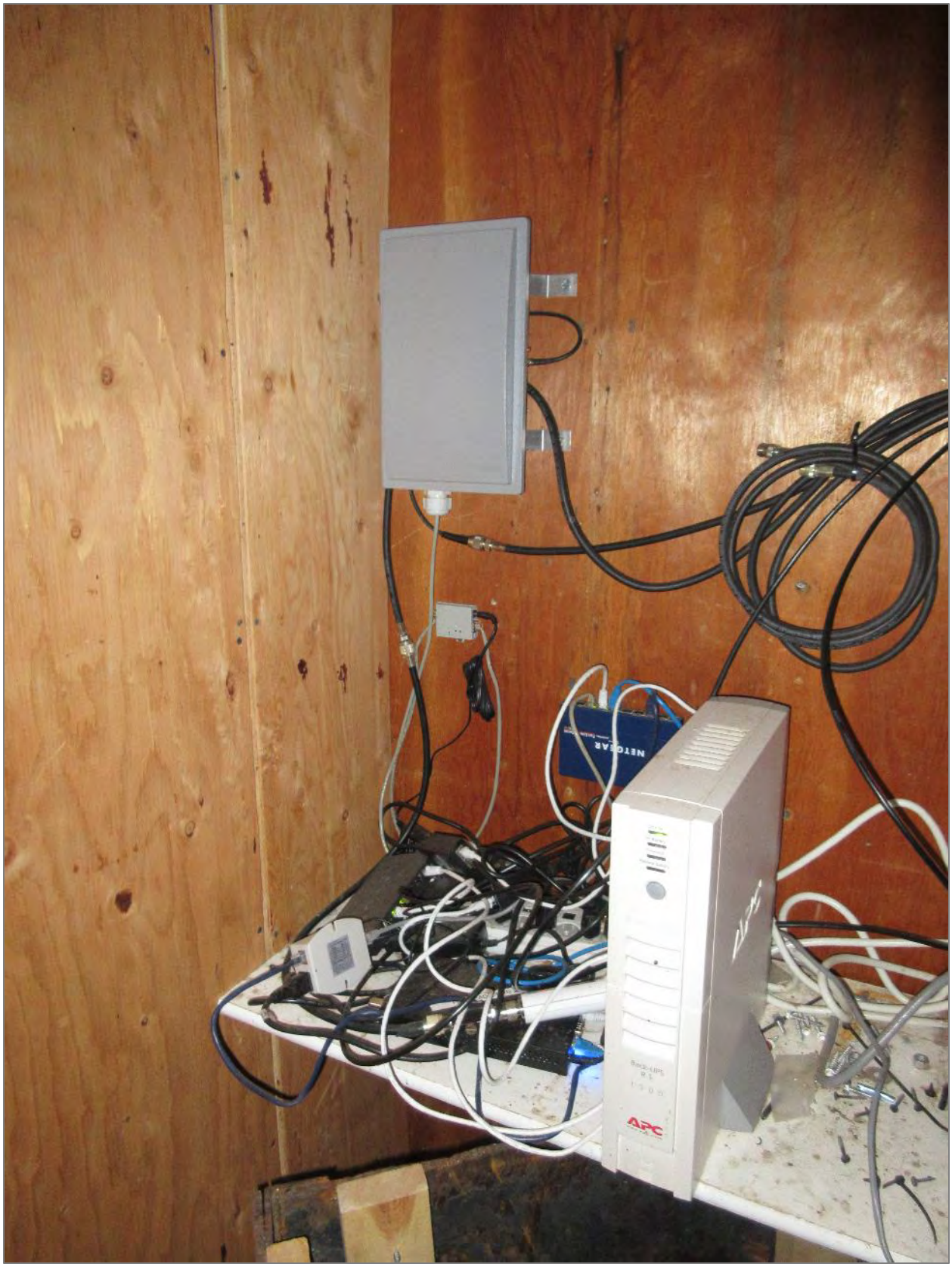
Photograph N-3

Photograph N-4

Photograph N-5

Photograph N-6

Photograph N-7



Photograph N-8

North Dome

Photograph ND-1

North Hill

Photograph NH-1

Photograph NH-2

Photograph NH-3

Photograph NH-4

Sheep Mountain

Photograph SM-1